AD-A102 023 FEDERAL AVIATION ADMINISTRATION WASHINGTON DC OFFICE --ETC F/G 5/1
NAS AUTOMATION EQUIPMENT OPERATING COST ESTIMATES, FY 1978-1984--ETC(U)
JUN 81 J COLLINS
UNCLASSIFIED FAA-APO-81-6 NL

END
DATE
FILMED
8 81
DTIC

15 LEVEL II

U.S. Department of Transportation
Federal Aviation Administration
Office of Aviation Policy and Plans
Washington, D.C. 20590

NAS Automation Equipment Operating Cost Estimates FY 1978-1984

AD A102023

DTIC
ELECTE
JUL 27 1981
S D
B

DTIC FILE COPY

FAA-APO-81-6

June 1981

Jerry Collins

Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
FAA-APO-81-6	AD-A102023	

4. Title and Subtitle	5. Report Date
NAS Automation Equipment Operating Cost Estimates, FY 1978-1984	Jun[redacted]81
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
Jerry Collins	
9. Performing Organization Name and Address	10. Work Unit No. (TRAIS)
Automated Services, Inc. 1483 Chain Bridge Road, Suite 200 McLean, Virginia 22101	
	11. Contract or Grant No.
	13. Type of Report and Period Covered
12. Sponsoring Agency Name and Address	
Department of Transportation Federal Aviation Administration Office of Aviation Policy and Plans Washington, D.C. 20591	
	14. Sponsoring Agency Code
	DOT/FAA/APO

15. Supplementary Notes

16. Abstract

This report provides summary information related to the cost of maintenance and support of certain system elements of the National Airspace System. Specific equipments for which support costs were developed include the major automation equipments of the enroute and the terminal air traffic control systems. The reader is reminded that this study effort was initiated prior to the formal establishment of the Computer Replacement Program and that the equipment under consideration for replacement is only partially matched by the list of equipment addressed in the study. The information developed should prove useful, however, in evaluating equipment common to both sets.

The equipments which are the basis for this report cost about $137 million in support and maintenance during FY 1979. Of this total, about $112 million (82%) was labor, $9 million (6%) was material and $16 million (12%) was services.

Of the total $112,218,000 of FAA labor, AIRWAY FACILITIES cost $78,947,000 (70%), AIR TRAFFIC software support was $30,027,000 (27%) and other labor was $3,244,000 (3%).

Support of the Enroute equipments cost $79,647,000 (58%) and Terminal equipments cost $57,339,000 (42%).

17. Key Words	18. Distribution Statement
NAS Automation Equipment Operating Cost Estimates	DISTRIBUTION STATEMENT A Approved for public release; Distribution Unlimited

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	85	

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

40648

TABLE OF CONTENTS

PAGE

EXECUTIVE SUMMARY i

SECTION 1 INTRODUCTION. 1-1

1.0 General 1-1
1.1 Methodology 1-2
1.2 Principal Results 1-5
1.3 AUTO/ECON Computer Cost Model 1-5
1.4 Automation Equipment Support Costs. 1-5
1.5 Conclusions 1-6

SECTION 2 AUTOMATION SYSTEMS. 2-1

2.1 Introduction. 2-1
2.2 Equipment Selected for Study. 2-2

SECTION 3 COST MODEL DESCRIPTION. 3-1

3.1 Introduction. 3-1
3.2 Cost Elements 3-2
3.3 Cost Model Implementation 3-5
3.4 AUTO/ECON Program Description 3-6
3.4.1 EXTRACTA Program 3-7
3.4.2 EXTRACTB Program 3-8
3.4.3 BASELINE Program 3-11
3.4.4 REPORTS Program. 3-12
3.5 Input Data. 3-13

SECTION 4 BASELINE (FY79) COST ELEMENTS. 4-1

4.1 Introduction. 4-1
4.2 Maintenance Labor 4-1
4 3 Site Support. 4-5
4.4 AF Training 4-7
4.5 Spares. 4-8
4.6 Test Equipment Maintenance, Calibration, and Repair . . . 4-9
4.7 Support Engineering 4-10
4.8 Automatic Data Interchange System, Service B. 4-10
4.9 Field Software Maintenance. 4-10
4.10 AT Training 4-10
4.11 Operational Software Support. 4-11
4.12 NAFEC Support 4-11
4.13 Region Cost 4-11
4.14 Headquarters Cost, Operations and Maintenance 4-12
4.15 Installation/Precommissioning Cost. 4-12
4.16 Future Refinements. 4-13

TABLE OF CONTENTS

SECTION 5 EXTENDED BASELINE ELEMENT ESTIMATES 5-1

5.1 Introduction. 5-1
5.2 Maintenance Labor 5-1
5.3 Site Support. 5-1
5.4 AF Training 5-3
5.5 Spares. 5-4
5.6 Test Equipment Maintenance. 5-4
5.7 Engineering Support 5-4
5.8 Automatic Data Interchange System, Service B. 5-5
5.9 Field Software Maintenance. 5-5
5.10 AF Training 5-5
5.11 Operational Software Support. 5-5
5.12 NAFEC Support 5-5
5.13 Region Cost 5-5
5.14 Headquarters Cost, Operations, and Maintenance. 5-5
5.15 Installation/Precommissioning Cost. 5-6
5.16 Acquisition Cost. 5-6

SECTION 6 COST ELEMENT SUMMARIES. 6-1

6.1 Introduction. 6-1
6.2 Automation Cost 6-1

SECTION 7 CONCLUSIONS 7-1

7.0 General 7-1
7.1 Observations and Recommendations. 7-1
7.1.1 Personnel Replacement. 7-2
7.1.2 Spares Cost. 7-2
7.1.3 Software Support Cost. 7-3
7.2 Cost Model Improvements 7-3

APPENDIX A SYSTEM DESCRIPTIONS. A-1

A-1.0 Introduction A-1
A-2.0 Enroute Systems. A-1
A-2.1 Air Route Traffic Control Center (ARTCC) A-1
A-2.2 Enroute Automated Radar Tracking Systems (EARTS) A-7
A-3.0 Terminal Area Systems. A-7
A-3.1 ARTS III/IIIA Systems. A-9
A-3.2 ARTS II System A-13
A-3.3 Radar Beacon Data Processing Equipment (RBDPE) A-16
A-3.4 Flight Data Entry and Printout (FDEP). A-17
A-4.0 Common Digitizer A-19

APPENDIX B REVISED COST DATA. B-1

LIST OF FIGURES AND TABLES

		PAGE
Figure 1-1	Cost Elements	1-4
Table 2-1	Equipment List	2-3
Figure 3-1	Extract Segments Flow Chart	3-9
Figure 3-2	Baseline Segment Overview	3-10
Figure 3-3	Reports Flow Chart	3-15
Table 4-1	Allocation of Support, Engineering, Management and Administrative Overhead to Automation ARTCC Sectors	4-4
Table 4-2	Rate A-1 - AF Maintenance, Enroute Center	4-6
Table 4-3	Installation/Precommissioning Cost	4-14
Figure 6-1	Automation Cost Summary	6-4
Figure 6-2	Category Cost Comparisons	6-5
Figure 6-3	Automation Maintenance & Support Costs for Fiscal Year 1979	6-6
Figure 6-4	Automation Maintenance & Support Costs for Fiscal Year 1980	6-7
Figure 6-5	Automation Maintenance & Support Costs for Fiscal Year 1981	6-8
Figure 6-6	Automation Maintenance & Support Costs for Fiscal Year 1982	6-9
Figure 6-7	Automation Maintenance & Support Costs for Fiscal Year 1983	6-10
Figure 6-8	Automation Maintenance & Support Costs for Fiscal Year 1984	6-11
Figure A-1	Enroute Center (ARTCC)	A-3
Figure A-2	ARTCC Automation System	A-4

LIST OF FIGURES AND TABLES (CONT'D)

Figure A-3	Enroute Computer/Display Systems	A-6
Figure A-4	Enroute ARTS (EARTS)	A-8
Figure A-5	Automated Radar Terminal System ARTS III	A-10
Figure A-6	ARTS II Automated Terminal System	A-15
Figure A-7	RBDPE (AN/TPX-42)	A-18
Figure A-8	Common Digitizer	A-20

EXECUTIVE SUMMARY

This report provides summary information related to the cost of maintenance and support of certain system elements of the National Airspace System. Specific equipments for which support costs were developed include the major automation equipments of the enroute and the terminal air traffic control systems. The reader is reminded that this study effort was initiated prior to the formal establishment of the Computer Replacement Program and that the equipment under consideration for replacement is only partially matched by the list of equipment addressed in the study. The information developed should prove useful, however, in evaluating equipment common to both sets.

Of equal importance to the cost data is the specific maintenance and support cost tabulator computer program which was implemented to support the cost development. Current cost information available to the agency is maintained on a mission oriented basis to support the funding process, not to support cost studies associated with specific equipments. The methodology of the study has been formalized into a cost tabulator supported by ADP computer programs available through the Office of Aviation Policy and Plans (APO). While specifically developed to support the Automation Systems Cost Study, the tabulator and support programs are sufficiently general to be adapted to other NAS system elements.

In addition to describing the specific methodology of the study and the computer programs developed, cost data has been generated for fiscal years 1979 through 1984, based on planned system configuration changes

and constant 1979 dollars. A summary of enroute, terminal and total automation maintenance and support costs are as follows for FY 1979.

	ENROUTE	TERMINAL	TOTAL
A. Labor Cost			
1. AF Labor	$41,785	$37,162	$ 78,947
2. AT Labor	18,961	11,066	30,027
3. Other	2,142	1,102	3,244
	62,888	49,330	112,218
B. Material Cost			
1. Direct Cost	3,879	1,065	4,944
2. Allocated Cost	3,000	750	3,750
Subtotal	6,879	1,815	8,694
C. Service Cost			
1. Direct Cost	3,581	3,407	6,988
2. Allocated Cost	6,299	2,787	9,086
Subtotal	9,880	6,194	16,074
TOTAL COSTS	$79,647	$57,339	$136,986

NOTE: FIGURES ARE IN THOUSANDS.

For comparison, of the total of $136,986,000, 82% is for specifically identified labor, 6% is for material and 12% is services. Of the labor total of $112,218,000, Airway Facilities accounts for 70% and Air Traffic (software support only - not operations) accounts for 27%.

Enroute system support is 58% of the total and Terminal systems is 42%.

The report provides detailed data on the support cost for ARTCC's (Central Computer Complex, Display Channel and DARC) for Common Digitizer and for EARTS. Terminal systems costs are detailed for ARTS III/IIIA, ARTS II, RBDPE (TPX-42) and Flight Data Entry and Printout (FDEP) equipments.

Based on the cost elements structure of the cost tabulator, it is possible to develop cost by site, by specific equipment or by region.

SECTION 1

INTRODUCTION

1.0 GENERAL. In the decade of the 70's the Federal Aviation Administration as well as every other operator of a complex command and control system, has had to develop innovative approaches for maintenance and support. The advent of the general purpose digital computer and its application to specific system needs has brought about many changes. In the case of the FAA, the drive for automation has been enhanced by greatly increased air traffic volumes and the constant pressure for improved productivity. Either factor would be an influence towards automation, but the combination dictates it. With the implementation of the computer based systems came the requirements for support of a new system element - software. At the same time, advances in electronics technology have made increasingly more complex systems possible. The FAA is currently planning the replacement of the air traffic control automation system to support enroute air traffic control. It is particularly important to understand the maintenance and support costs of the present system during the development of requirements for the replacement system.

Development of maintenance and support costs within the agency is not as straightforward as might be assumed. The FAA, of necessity, has developed its budgetary and cost control systems on a mission oriented basis to support its two major sources of funds. The Facility and Equipment (F&E) budget supports the acquisition and implementation of new or modified systems, equipments and facilities. The F&E budget is largely Headquarters developed in accordance with specific program or project cost estimates. The Operating and Maintenance (O&M) budget

supports the ongoing operation of current facilities and sites. The O&M budget is largely regionally developed, in accordance with headquarters guidance, by field organization.

The major cost driver for the F&E budget is new equipment acquisition. The major cost driver for the O&M budget is personnel. Headquarters support of the O&M budget process is in the development of staffing guidelines or standards for the operational field organizations. Each region is responsible for developing detailed O&M budget requests based on the headquarters guidelines and their local conditions. In this process of developing budgets for each sub-organization and providing cost tracking to the budget, it becomes increasingly difficult to answer questions related to the true support cost of a specific system or equipment.

This NAS Automation Cost Report is based on the development of a cost model whose elements can be estimated by equipment and by function. Thus, it serves as a tool for the development of an understanding of the maintenance and support costs of specific equipments in accordance with current practices and procedures.

1.1 METHODOLOGY. The compilation of the cost of maintenance and support for specific equipments within the National Airspace System (NAS) requires diligent, dedicated and at times creative effort. The definition of a set of cost elements that can be combined in meaningful ways and at the same time can be supported with rational estimates of current and future costs is not a trivial task. The NAS equipment installed base is constantly changing. The systems, procedures and practices at sites within a given region are generally quite consistent,

but there are significant variations between regions based on the [illegible] conditions and management approaches of the region.

The general methodology of the study was to identify and [illegible] specific equipments under consideration, to develop the elements of labor, materials and services which are significant cost contributors and to provide a consistent system for handling costs and their accumulation.

The equipments chosen for study include:

A. ENROUTE

1. Air Route Traffic Control Center (CONUS)
    a. Central Computer Complex (CCC)
    b. Display Channel (CDC or DCC)
    c. Direct Access Radar Channel (DARC)

2. Remote Sites
    a. Common Digitizer

3. Enroute Automated Radar Tracking System

B. TERMINAL

1. ARTS III/IIIA
2. ARTS II
3. RBDPE (TPX-42)
4. FDEP

The labor, material and service cost elements are shown in Figure 1-1.

CATEGORY DESCRIPTION

- A. LABOR COSTS
  - 1. AF LABOR
    - a. FIELD MAINTENANCE
      - 1) TECHNICIAN DIRECT
      - 2) SUPERVISION & ADMINISTRATION
      - 3) SITE SUPPORT

      SUB-TOTAL AF LABOR
    - b. ENGINEERING SUPPORT
      - 1) NAFEC HARDWARE SUPPORT
      - 2) NAFEC SOFTWARE SUPPORT

      SUB-TOTAL ENGRG SUPPORT
    - c. ALLOCATED LABOR COSTS
      - 1) REGIONS
      - 2) HEADQUARTERS

      SUB-TOTAL ALLOCATED AF LABOR

    TOTAL AF LABOR
  - 2. AT LABOR
    - a. DIRECT SYSTEMS SUPPORT
      - 1) FIELD SOFTWARE SUPPORT
      - 2) NAFEC SOFTWARE SUPPORT

      SUB-TOTAL DIRECT SYSTEMS SUPPORT
    - b. ALLOCATED LABOR COSTS
      - 1) REGIONS
      - 2 HEADQUARTERS

      SUB-TOTAL ALLOCATED AT LABOR

    TOTAL AT LABOR
  - 3. OTHER LABOR
    - a. DIRECT SYSTEMS SUPPORT
      - 1) AF ACADEMY / INSTRUCTORS
      - 2) AT ACADEMY / INSTRUCTORS

      SUB-TOTAL DIRECT SYSTEMS SUPPORT
    - b. ALLOCATED OTHER LABOR COSTS
      - 1) ENGINEERING SUPPORT (SRDS)
      - 2) DEPOT SUPPORT

      SUB-TOTAL ALLOCATED OTHER LABOR

    TOTAL OTHER LABOR

  TOTAL LABOR COSTS
- B. MATERIAL COSTS
  - 1. DIRECT MATERIAL COSTS
    - a. SPARE PARTS
    - b. MODIFICATION KITS

    SUB-TOTAL DIRECT MATERIAL COSTS
  - 2. ALLOCATED MATERIAL COSTS
    - a. EXCHANGE & REPAIR PROGRAM

  TOTAL MATERIAL COSTS
- C. SERVICE COSTS
  - 1. DIRECT SERVICES COSTS
    - a. SITE ENERGY
    - b. ACADEMY TRAINING
      - 1) PER DIEM
      - 2) TRAVEL
    - c. TEST EQUIPMENT SUPPORT

    SUB-TOTAL DIRECT SERVICES COSTS
  - 2. ALLOCATED SERVICES COSTS
    - a. NAFEC COSTS
      - 1) AF SUPPORT CONTRACTS
      - 2) AT SUPPORT CONTRACTS
      - 3) FACILITIES SUPPORT
      - 4) DOCUMENTATION SUPPORT

      SUB-TOTAL NAFEC COSTS
    - b DATA COMMUNICATION

    SUB-TOTAL ALLOCATED SERVICES COSTS

  TOTAL SERVICES COSTS

TOTAL ALL COSTS

FIGURE 1-1

COST ELEMENTS

The AUTO/ECON automatic data processing software system was developed to automate the computation of cost elements over a twenty-year period based on cost element data for a baseline year and with economic parameter and system equipment configuration changes on an annual basis.

1.2 PRINCIPAL RESULTS. The principal deliverables of this study are the AUTO/ECON computer software and supporting documentation and this cost report. In addition to providing a level of insight into the basic costs associated with the support and maintenance of current automation equipments, the study provides a cost estimating methodology and support system which could be made applicable to any of the agency's systems.

1.3 AUTO/ECON COMPUTER COST MODEL. The Systems Analysis Division in Aviation Policy and Plans (APO-200) will install and maintain the AUTO/ECON computer cost model to provide additional cost estimating support for ongoing projects. The attributes of the system are generally described in other sections of this report.

1.4 AUTOMATION EQUIPMENT SUPPORT COSTS. The equipments which are the basis for this report cost about $137 million in support and maintenance during FY 1979. Of this total, about $112 million (82%) was labor. $9 million (6%) was material and $16 million (12%) was services.

Of the total $112,218,000 of FAA labor, Airway Facilities cost $78,947,000 (70%), Air Traffic software support was $30,027,000 (27%) and other labor was $3,244,000 (3%).

Support of the Enroute equipments cost $79,647,000 (58%) and Terminal equipments cost $57,339,000 (42%).

Additional cost estimate summaries by facility type for each year from 1979 to 1984 are included in section 6 of this report. In addition, cost estimate summaries by specific site, equipment and region have been provided to APO-200, but not included in this report.

1.5 CONCLUSIONS. This cost study has provided a cost estimating methodology for system support and maintenance within the FAA. The methodology was applied to specific automation equipments currently in the inventory. As a result, a meaningful set of support cost data has been compiled which will be useful for future cost/benefit analysis of improved and/or new systems.

Users of the AUTO/ECON model and/or cost data presented in this report are reminded that because of difficulties involved with identifying, acquiring, and formatting this information, the potential for estimation errors increased, and should not be overlooked. The overall validity of the methodology developed by the analysis, however, should remain virtually unaffected.

SECTION 2

AUTOMATION SYSTEMS

2.1 INTRODUCTION. Automation systems, for the purpose of this study have been specifically defined to include only certain equipment. The major criterion for selection of specific types of equipment was that the primary function performed is digital data processing. Thus, the enroute automation systems have been structured to include the Common Digitizer (CD), but exclude the long range surveillance radar (ARSR), remote microwave link (RML), and plan view displays. Similarly, terminal area systems exclude the airport surveillance radar (ASR), and display systems. In addition, no attempt was made to develop estimates regarding equipments to be implemented through the Flight Service Station, ETABS or TIPS programs on the premise that they were still within the development phase and as a result needed further definition to allow accurate estimates of support costs. Therefore, the terms "NAS Automation" and "automation equipment", as used in this report are not generally inclusive and should not be considered in any other context.

The air traffic control automation systems have the basic objective of providing the air traffic controller with aircraft position and identification data in real time. Auxiliary data processing functions are also provided to reduce the controller's workload or to provide additional service. The major result obtained from each system is a two dimensional display with aircraft position indicated by a radar target blip and symbol, supplemented by geographic or sector data to provide references. An alphanumeric may appear adjacent to the indicated aircraft position to identify it and its altitude. A flight strip printer provides advance notice of flight plans which define the expected route and altitude for a specific aircraft and radar/beacon surveillance

system which provide current position, identity and altitude. The basis for this study are the computer based systems that process and display this data (9020, ARTS III and ARTS II); the hardwired TPX-42 (RBDPE) and selected support equipment and services, including the Flight Data Entry and Printout Equipment (FDEP); leased communications lines (Service B) of the Automation Data Interchange Network; and the Common Digitizer.

2.2 EQUIPMENT SELECTED FOR STUDY. Table 2-1 lists the specific equipments selected for analysis in this study.

An Appendix to this document contains a summary description of the data processing and display system, FDEP and CD as understood by the contractor. This information is important to illustrate the assumptions and understandings from which the cost estimates in the text were developed. It is recognized that the configuration descriptions in the appendix are not completely accurate. However, the errors do not impact the cost estimates developed in the study.

EQUIPMENT LIST

Equipment	Location	FY1979 Baseline	Extended Baseline
Common Digitizer	Remote ARSR	CD	CD-2
Computer Central Complex	Enroute Center	CCC	CCC
Computer Display Channel	Enroute Center	CDC	CDC
Display Channel Complex	Enroute Center	DCC	DCC
Direct Access Radar Channel*	Enroute Center	*	DARC
Automated Radar Terminal System	Major Terminals	ARTS III	ARTS IIIA
	Smaller Terminals	(None)	ARTS II
Enroute Automated Radar Tracking System	Anchorage, AL	EARTS	EARTS
	Honolulu, HI	ARTS III	EARTS
	San Juan, P.R.	ARTS III	EARTS
	Nellis AFB	RBDPE	EARTS
Radar Beacon Data Processing Equipment	Small Terminals	RBDPE	RBDPE
Flight Data Entry and Printout Equipment	CONUS	FDEP	FDEP
Automated Data Interchange System, Service B	CONUS	ABDIS	ABDIS

* Broadband (radar video) equipment was excluded from the baseline on the premise that this is not automation equipment. However, its replacement (DARC system) is automation equipment and was included in the extended baseline.

TABLE 2-1

SECTION 3

COST MODEL DESCRIPTION

3.1 INTRODUCTION. FAA program management relies on cost data as one of the inputs to the project authorization decision process. As a project proceeds through to implementation, alternative approaches are considered which are again subject to cost/benefit analysis. Generally, there are a few cost factors which can be readily identified and analyzed which form the basis for these decisions. In the implementation of major programs, such as the presently evolving computer replacement program for the enroute air traffic control systems, the cost of supporting the present system is not easily quantified. A major reason for this is the budgeting and cost tracking system. Two of the major sources of funds for the agency are the Facilities and Equipment (F&E) budget and the Operating and Maintenance (O&M) budget. The annual budget requests are prepared in great detail in a format which provides visibility for review purposes. As might be expected, obligations and expenditures are tracked in the same framework that the budget estimates were prepared. The basis for the F&E budget is a combination of specific projects, usually involving the acquisition of new equipment or the modification of existing equipment. The O&M budget is developed based upon estimates from the lowest organization level and consolidated into a mission oriented budget. Thus, we find that one cost tracking process (F&E) is related to systems and equipment and the other (O&M) is related to organization structure and missions. Attempting to interrogate the O&M cost tracking system to determine the actual cost of supporting a specific system or equipment becomes very difficult. One is forced to construct a model and estimate the value of each element.

In the development of a cost model, there are a number of factors to be

considered. What is the application and purpose of the cost estimate? The cost elements chosen must be readily identifiable, meaningful and quantifiable. What are the sources of reasonable cost data? Have the significant cost elements been chosen?

For the purpose of the NAS Automation Cost Study, it was determined that a specific set of equipment (described in Section II) would be the basis for the study. The general costs of interest were the labor, material and services required to support and maintain that equipment. The basic criteria for inclusion was that the cost element being considered be directly attributable to the support and maintenance of the selected automation equipment base. By implication, excluded costs include users and operators of the systems, such as air traffic controllers.

Because of the number of cost elements to be considered and the desire to formalize the cost development methodology, a decision was made to use automatic data processing (ADP) in the implementation of the cost model. A series of software programs were developed (AUTO/ECON) to assist in the cost analysis. A major data source for AUTO/ECON is the AF Staffing Standard report because of its structure, organization and availability in computer compatible format.

The following paragraphs describe the specific costs elements, the AUTO/ECON software and the data sources for this study.

3.2 COST ELEMENTS. Applicable costs are organized into labor, material and services categories. Labor costs are subdivided into AF, AT and other. Materials include spares and modification kits. The services category includes such elements as site energy, applicable NAFEC and

academy costs, selected communication costs and test equipment calibration and repair costs. These cost elements were chosen after initial study had indicated that these were the major cost contributors to automation equipment support and maintenance. In addition, specific sources of cost data were identified for each element.

The cost model can be envisioned as cost elements in a three dimensional matrix. One axis identifies the specific cost elements. Systems and equipment comprise the second axis and the third axis is time by fiscal year. The hierachical structure for the cost elements is as follows:

A. LABOR

1. AF Labor
   a) Field Maintenance
      1) Technician Direct Work
      2) Engineering and Management
      3) Site Support, Environmental Unit
   b) Engineering Support and Management
      1) NAFEC Hardware Support
      2) NAFEC Software Support
      3) Regions
      4) Headquarters

2. AT Labor
   a) Field Software Support
   b) NAFEC Software Support
   c) Regions
   d) Headquarters

3. Other Labor

   a) Academy

      1) AF Training

      2) AT Training

   b) Depot Support

   c) RD&E Support

B. MATERIAL

1. Spare Parts

   a) Purchased Spares

   b) E&R Program

2. Modification Kit Costs

C. SERVICES

1. Site Energy

2. NAFEC Costs

   a) AF Support Contracts

   b) AT Support Contracts

   c) Facility Support

   d) Documentation Support

3. Data Communications

4. Academy Training

   a) Per Diem

   b) Travel

5. Test Equipment Calibration and Repair

The structure of the facility equipment is by location within region. Locations are further identified as enroute or terminal area sites. The equipment structure is as follows:

A. Enroute Systems

1. ARTCC

    a) CCC

    b) CDC

    c) DCC

    d) DARC

2. EARTS

3. Remote

    a) CD (ARSR Site)

    b) FDEP (Various sites)

B. Terminal Area Systems

1. ARTS

    a) ARTS II

    b) ARTS III

    c) ARTS III-A

2. RBDPE

Where possible, cost estimates for an element have been made system specific. Some cost estimates are more generally applicable to either enroute or terminal environments and others are applied to automation systems in general. Where there is no reasonable basis for cost allocation to a specific element, the cost model makes provision for cost estimate entry at the sub-total level. These entries are referred to as "totals only" data.

3.3 COST MODEL IMPLEMENTATION. The NAS Automation Cost Model has been implemented to be supported by automatic data processing. The software has been developed to operate on an IBM 360/65 computer with OS 21.7

HASP/MVT as the operating system. Required computer resources are 256k bytes of memory and 250 tracks of IBM 3330 disk memory. The programs assume that data input files required are available on disk. These disk files must be created prior to executing the AUTO/ECON programs. Typically, the AF Staffing Standard report file would be read in from magnetic tape and held in a temporary disk storage file of an additional 500 tracks until both extract programs have been executed successfully. Other data files required can be prepared and read in from punched cards at a remote job entry station.

Detailed documentation of the AUTO/ECON Cost Model Programs has been separately provided to the FAA. It is planned that the programs will be installed under the auspices of Aviation Policy and Plans (APO).

3.4 AUTO/ECON PROGRAM DESCRIPTION. The Automation Economics (AUTO/ECON) cost model program provides the facility for structuring maintenance and support costs of a selected set of FAA equipment. The software has been developed to accept cost element estimates for both hardware and software activities. The cost report structure is based on the FAA's automation systems support organization. Personnel (head count) data is accepted for both AT and AF organizations at the local, regional and national level. In addition, level of effort estimates are accepted for NAFEC, the Academy and the Depot.

For the purpose of the NAS Automation Cost Study, the equipment list is defined in Table 2-1. It should be noted that the application of the AUTO/ECON software is not restricted to this limited equipment list. The software was developed using a generalized approach and can be adapted to provide similar cost reports for other NAS systems and equipment. One

feature of the program is the use of the AF Staffing Standard report as the source of data for equipment, facilities and locations. Other data are also extracted and used, but these provide an automatic means for updating the equipment list by location. Other data, such as economic parameters and other cost estimates must be manually generated.

AUTO/ECON has four separate computer programs: EXTRACTA, EXTRACTB, BASELINE and REPORTS. The EXTRACTA AND EXTRACTB programs are used to create the required working files from the AF Staffing Standard file. BASELINE is the cost analysis program and REPORTS is the cost report writer program. This program structure provides flexibility in the development of required cost reports. For example, only a single run of EXTRACTA and EXTRACTB is required for each release of the AF Staffing Standard. Multiple runs of BASELINE might be made with various economic parameter data. Similarly, several runs of REPORTS might be made to yield either summary only or detailed cost reports for each run of BASELINE.

Functional flow charts of the segmented programs are shown in Figures 3-1 and 3-2.

3.4.1 EXTRACTA PROGRAM. The EXTRACTA program produces a complete or partial list of commissioned facilities/equipment, by location, within the NAS. The source of this data is Book 2A of the AF Staffing Standard. The user specifies the types of facilities/equipment that are to be extracted by creating a list file with the four (alphanumeric) character facility codes/designations.

This program also extracts AF labor (man hours) information for Allocated

Training, Total Direct Work, and Support & Administrative. The information comes from Book 1C of the AF Staffing Standard.

Input for this program is a single file of the facility/equipment types to be extracted. It is assumed that Books 1 and 2A have already been copied onto a single disk file. Output of this program is a single list of facilities, by location.

It is possible, and perhaps desirable, to extract all of the facility types needed for any anticipated analysis with this program. Then the cost analysis program can be used to select only those facility types which are to be analyzed in a particular run. In other words, the analysis program can further narrow the focus of attention for each run; whereas, the extract file should contain all of the facilities/equipment which might be used in any one of several analysis runs.

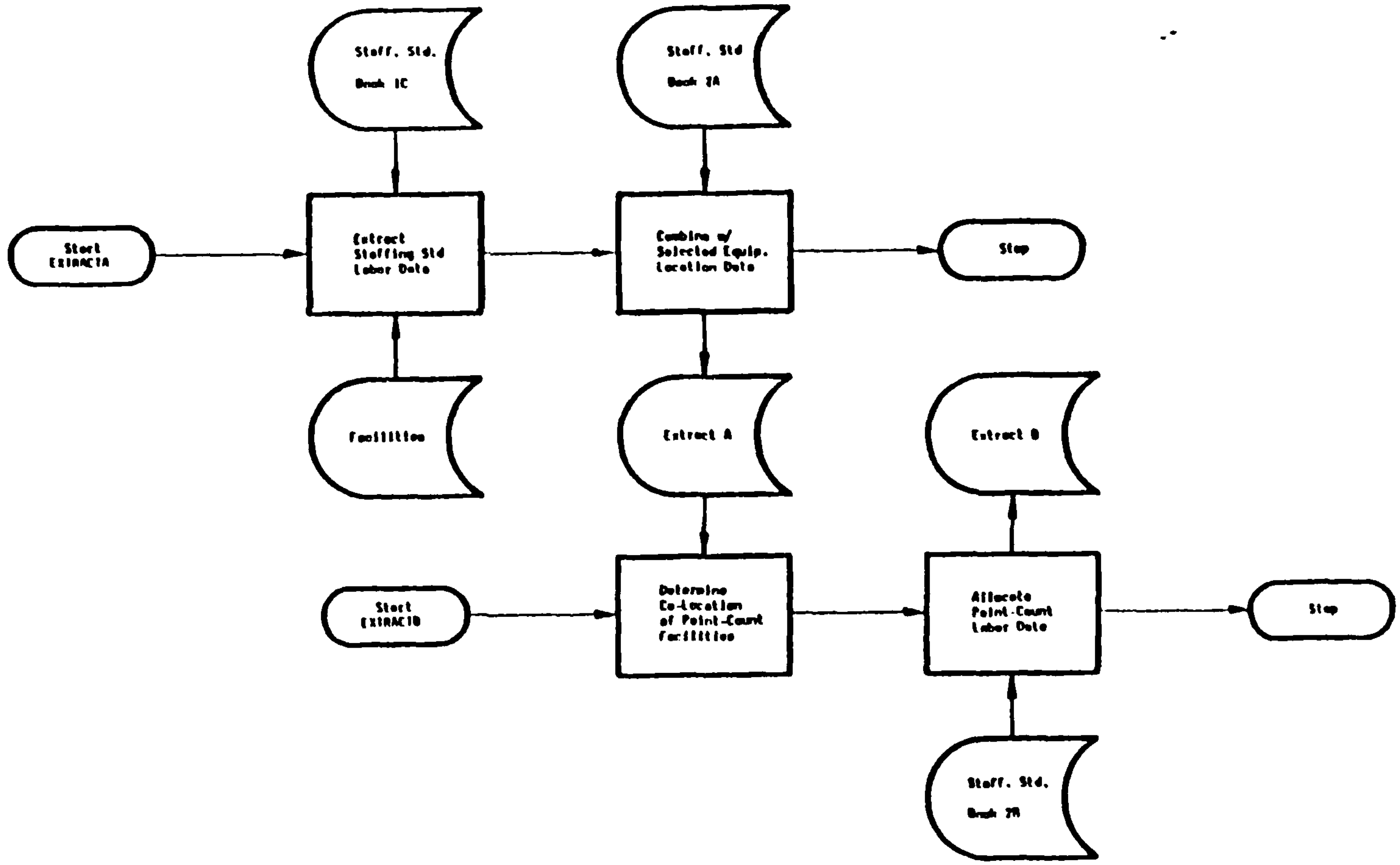
3.4.2 EXTRACTB PROGRAM. The EXTRACTB program produces a list of sectors, by region, in which selected facilities/equipment are located. The selected facilities are those included in the output file from running the EXTRACTA program. This program also extracts AF labor (man years) information for Engineering, Management, and Administration related to automation equipment. The source of this data is Book 2B of the AF Staffing Standard.

Input for this program is only the output file of the EXTRACTA program. It is assumed that Book 2B has already been copied onto a single disk file. Output of this program is a single list of sector locations, by region. The program should be rerun each time the EXTRACTA program is rerun.

DIAGRAMMING AND CHARTING WORK SHEET

Auto From CMP

FUNCTIONAL FLOW CHART

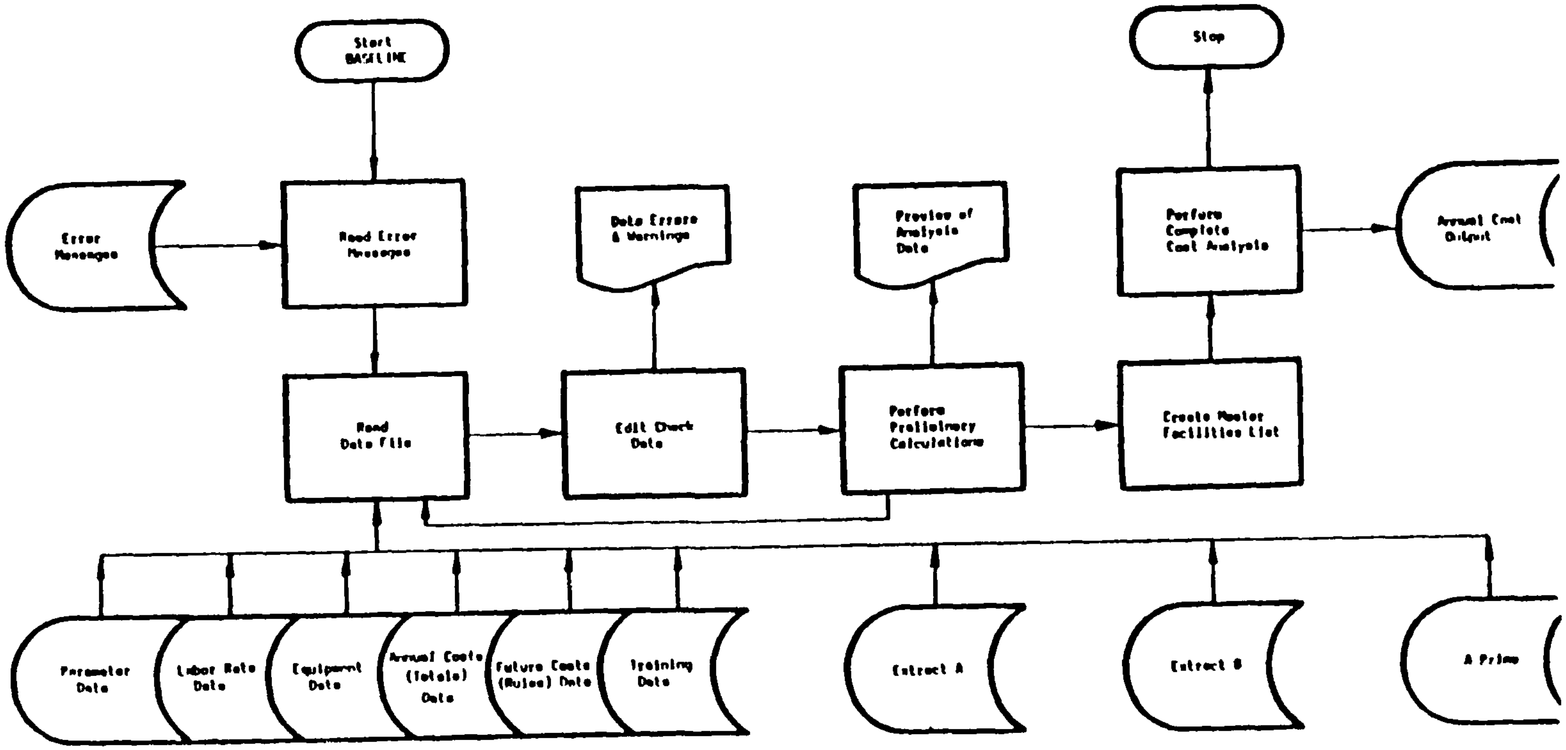


EXTRACT SEGMENTS FLOW CHART

FIGURE 3-1

DIAGRAMMING AND CHARTING WORK SHEET — Auto Econ LMP

FUNCTIONAL FLOW CHART



BASELINE SEGMENT OVERVIEW

FIGURE 3-2

The reason that the two extract programs are programmed and run separately is because the EXTRACTB program is required only for "point count" facilities (See FAA Order 1380.40).

3.4.3 BASELINE PROGRAM. The BASELINE program is the cost analysis program. It produces a complete cost analysis for support and maintenance of NAS automation equipment. These costs are computed on a fiscal year basis. They are of two types: costs associated with particular facilities/equipment and aggregated costs for the entire system (referred to as "totals only").

The principal input for this program is the output file from the EXTRACTA program. It contains a list of the specific facilities to be analyzed (with, perhaps, some others that may not be analyzed). Another significant input for this program is the output file from the EXTRACTB program. The remaining input files to this program are manually prepared. They include economic parameter information, totals only information and training information.

Also, future facilities/equipment are contained in a separate file with a format similar to, but not identical with, the EXTRACTA program output file. The future facilities file (referred as an APRIME) also indicates the previously commissioned facilities being replaced, if any. A separate file of "rules" indicates revisions over time to facility/equipment values and to totals only values.

The user is responsible for the accuracy and consistency of all of these input data files. Many edit and consistency checks are made by the program, but subtle or systematic errors may not be detected. Even the

extract files from the AF Staffing Standard should be reviewed for correctness and desirability before proceeding with the cost analysis.

The only other input file is a list of error messages indexed to those edit and consistency checks. If the wording or severity of the errors are not suitable to the user, they can be easily changed by modifying this file (without having to change the program itself).

Output of the program is one large disk file containing the annual costs for each facility/location and for totals only. Facility/equipment costs are broken down into approximately 23 separate categories, and totals only cost are broken down into approximately another 15 categories. The complete cost breakdown is generated for each year within the period specified by the user. Some procedural and diagnostic/error messages are also printed during the course of a run.

3.4.4 REPORTS PROGRAM. The REPORTS program can produce several output reports for cost analysis. Report 1.1 is a very detailed report format which lists each facility/equipment by location and identifies all costs for a specified one year period. All totals only costs are also identified for that one year period.

Report 1.2 is a somewhat more aggregated report format. It summarizes costs by facility/equipment type and by totals only category. These costs are for a specified year, or a group of consecutive years. Report 1.4 is a summary report for one or more years in which all costs are aggregated by each of the almost 40 cost categories.

IMPORTANT!! The user should be aware that certain cost categories

associated with facilities/equipment are contained in other cost categories. As a result, the annual totals (which are calculated across the report page) exclude certain cost categories (to prevent double counting). Specifically, the cost categories which are not separately included in the annual totals are: AF MAINT. TRAINING ALLOWANCE, AF TRAIN. STUDENT LABOR, TEST EQPT LABOR, and AT TRAIN. STUDENT LABOR.

The principal input for this program is the cost analysis results produced by the BASELINE program. Another input is the array formatted file which specifies cost category headings for the various reports. The user can change these, if desired. The only other input is a series of punched cards (or card images on a disk file) which specify the reports to be generated, and the relevant particulars thereto. The user can specify reports which include only selected facility/equipment types and/or years. For Report 1.2, the user can also define special subtotals of selected facility/equipment types.

A functional flow chart of the REPORTS program is shown in Figure 3-3.

3.5 INPUT DATA. AUTO/ECON requires that certain data files be available on the system disk. This data may be input from punched cards from a remote job entry station. A summary of data, other than the AF Staffing Standard report is as follows:

a) Facility Codes - One set of codes defines the list to be extracted from the AF Staffing Standard report. A second set can be used, if desired, to restrict BASELINE and REPORTS to a subset of the extracted data file.

b) Parameter Variables - Data used to define the baseline year, number of years and generally applicable economic data.

c) Labor Rates - Government employee average labor rates and allocation by GS-level.

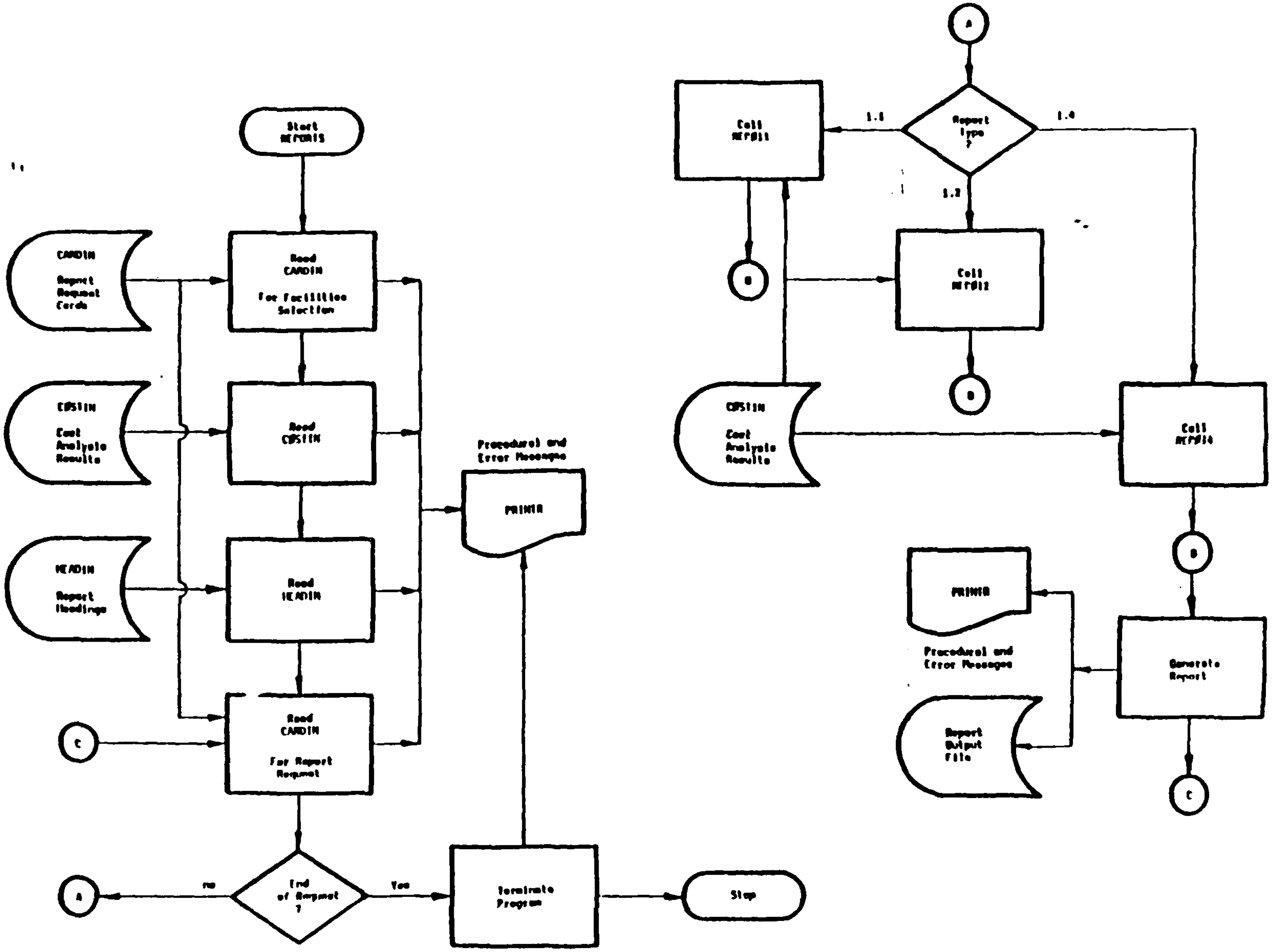
d) Equipment Parameters - Special cost parameters associated with a particular equipment.

e) Totals Parameters - Cost estimates to be included as "totals only" which are not associated with a particular equipment.

f) Rules - Specific instructions for modifying selected equipment and/or "totals only" parameters.

g) Academy Course Costs - Costs by course number for academy training with application data.

h) APRIME Table - The list of future facilities to be commissioned with commissioning dates. Commissioning of future facilities is also derived from the AF Staffing Standard report. The user may choose which data source is used by an appropriate flag on each data entry.



REPORTS FLOW CHART
FIGURE 3-3

SECTION 4

BASELINE (FY79) COST ELEMENTS

4.1 INTRODUCTION. Estimates of the cost of individual cost elements are based on data gathered from a variety of sources. As has been noted, a major source of data is the AF Staffing Standard Report. In addition to providing sector level maintenance standards, this report also provides facility, location and equipment information. In the process of developing the cost model, data was developed for both FY78 and FY79 as baseline years. The following sections describe the source of information and the rationale for developing each of the cost model element estimates.

4.2 MAINTENANCE LABOR. The AF Sector Level Staffing Standards contain the standard allowances in manhours for each equipment number and class code in Books 1A, 1B, and 1C. Book 2A lists the equipment in each sector within each region. It also provides sector summaries of the standard allowances. In Book 2B, the sector summaries are recompiled in accordance with other criteria for training allowance and support and administrative allowances of FAA Order 1380.4. These sector staffing allowances are the basis for budgets and also for the actual staffing of each sector.

Book 2A provides the equipment number, class code, sector, and location of all the automation equipment in commissioned status. Using this information and Book 1C, we are also to determine the standard allowance total for automation equipment at each field location. From Book 2B, we obtained the sector allowance for technical staff, supervision staff, administrative staff, and the sector total.

On field trips to several automation facilities, data was obtained to determine the size and content of the automation staff and to allocate to automation part of the technical, supervision, and administrative staff. We also allocated part of the environmental support unit staff to automation. The Sector Manager and staff at each location visited assisted us with organization charts, local knowledge of circumstances, and suggestions. Generally, we found the sector staffing authorized was the same as the Book 2B sector total. The assignments to automation, however, differed slightly from place to place. Also, the division of software responsibilities between AF and AT was not the same at all ARTS III sites, resulting in some variation in AF software positions.

We visited two of the five enroute centers which have the CCC/DCC equipment - Aurora at Chicago and Islip at New York. In each, the number of automation positions allowed is about 10% less than the standard allowance. In total it averaged 9%; therefore, we decided to reduce the standard staffing by 9% at these five centers, to more closely reflect the actual maintenance labor cost.

At four of the fifteen enroute centers with the CCC/CDC equipment, we found the automation staffing positions allowed varied from the standard allowance to almost 20% more than the standard allowance. Therefore, we decided to increase the standard allowance by the average of 10% over standard staffing to reflect actual maintenance labor cost.

The AF technical staff, supervision, engineering, and administrative staffs are not assigned 100% to automation. There is a large amount of other equipment and responsibility for them to handle. Included in this group are the programmers (SPS), computer operators (CO), system engineers

(SE, ASE), systems performance officer (SPO), and crew supervisors who are allocated 100% to automation. The others, technicians-in-depth (TID), supply clerks, and administrative staff are allocated partly to automation. At each location, the Sector Manager or Assistant Manager and SPO assisted us with these allocations. These estimates depict a consistent pattern which we have averaged for this purpose.

Table 4-1 illustrates the allocation of Sector Support, Sector Engineering Management, and Administrative Overhead to Automation. This allocation is substituted for the Support and Administrative allowances of the automation equipment in Book 1C. As a result, the relationship of Direct Work to S&A is significantly changed. For example, the Direct Work Standard for a CCC and CDC totals 41803 hours or 20 positions. S&A is 16938 hours or 8 positions. Applying the Point Count Method and allocation, S&A is 33.9 positions and the automation total is 53.9 positions. It is apparent that most of the positions allocated are 100% full-time automation positions in much the same sense as "Direct Work" performed by technicians. Only 2.8 positions of Administrative Overhead are allocated to automation.

The Direct Work allowance includes direct maintenance, inspections, modifications, travel, documentation, training, personal activity, leave and holiday. It is clearly intended to cover 40 hours per week, 52 weeks a year, or 2080 hours a year.

A similar allocation has been applied to ARTS III sectors. The result is that S&A automation positions are more than three times the number of Direct Work automation positions in these sectors. In those few instances where one sector has more than one ARTS III, the sector S&A

TABLE 4-1

ALLOCATION OF SUPPORT, ENGINEERING, MANAGEMENT AND ADMINISTRATIVE OVERHEAD TO AUTOMATION ARTCC SECTORS

Position Title	Positions	Allocation To Automation
Systems Performance Specialist	5	5.0
Staff Engineer/Technician-In-Depth	5	2.5
Field Logistics Spec./Supply Clerk	3	0.6
Computer Operator	7	7.0
Systems Engineer/Asst. Sys. Engr.	10	10.0
Systems Performance Officer	1.0	1.0
Environmental Support Engr.	1.0	---
Asst. Env. Supp. Engr./Engr. Tech.	1.0	---
Crew Supervisor	10.0	5.0
Sector Manager	1.0	0.4
Asst. Sector Manager	1.0	0.4
Secty/Steno./Clerk Typist	3.0	1.2
Proficiency Dev. & Eval. Offr/Staff	2.0	0.8
	50.0	33.9

automation allocation has been divided evenly among them.

The staffing standards do not indicate the grade levels of automation maintenance personnel. However, the organization charts, which we obtained, show the grade level for each position. The salary schedule for each grade level (General Schedule) was furnished by the COTR for the baseline period. It reflects the actual average salary within the salary range of each grade level. Using the above data, we formulated an allocation table for the typical AF staff at enroute centers, terminal centers, etc., and calculated the average annual salary applicable. Fringe benefits and overtime allowance are added at 15%. This figure represents a composite of the standard 10% figure used by the FAA Office of Budget for costing fringe benefits plus 5% taken as an average figure for overtime based upon the national average for all AF and AT personnel.

The cost model and computer programming utilize these tables in separate subroutines so that they are temporarily stored and referred to as the computations are run. The information contained in the tables, rates, allocations, fringe benefits, etc., can be readily changed if desired, without any change to the computer program. Table 4-2 is an example of an allocation table and rate calculation.

4.3 SITE SUPPORT. Recurring site support costs of labor and energy were investigated. The environmental support unit (ESU) at each center consists of a supervisor and several maintenance technicians. We discussed the allocation of this workforce to automation with the Sector Manager and ESU Supervisor at each center that we visited. For enroute centers, the consensus was clearly an allocation of 8 of the ESU staff of 20 or 21, and for ARTS III terminal sites, 1.5 out of the ESU staff of 8

TABLE 4-2

RATE A1 - AF MAINTENANCE, ENROUTE CENTER

GS #	Positions	Allocation	Alloc. x Total Comp., S1 $ x 1000
15	1	0.4	18.48
14	6	2.9	113.88
13	16	8.0	265.76
12	16	15.0	419.10
11	15	14.0	326.48
10	0	--	0.00
9	10	10.0	192.50
8	3	2.2	38.48
7	1	0.2	3.15
6	1	0.4	5.68
5	0	--	0.00
4	1	0.4	4.53
	70	53.3	1,387.96

$$\text{Rate A1} = \frac{1387960.}{53.3}$$

$$\text{A1} = \$25{,}940.$$

NOTE: Total Comp., S1 is the 1978 General Schedule with 15% fringe benefit and overtime allowance added.

to 10. These costs are included in the Staffing Standards and, therefore, cannot be included again in adding automation cost.

We obtained month-by-month total energy cost for several locations. From these, we determined cost per KWH. Rates varied from 2.3¢ per KWH to 6.5¢ per KWH in 1978 and 1979. We obtained a report from the Electric Power Research Institute (EPRI) at Palo Alto which indicated the national average rate in 1978 was $0.04 per KWH - the mid-point of the range indicated by the FAA data. Therefore, we accepted $0.04 per KWH as a representative average.

At enroute centers, it was agreed that the energy requirement for automation is approximately equal to the power on the critical bus. From several measured values available, we determined an average of 2.9 million KWH for an enroute center for automation equipment.

At ARTS III terminal centers, we obtained available measurements of current on ARTS III distribution circuits, and a copy of a power study performed at Atlanta. From these we estimated the average annual energy at 735,000 KWH for automation.

4.4 <u>AF TRAINING</u>. AF automation course numbers were selected from the FAA Catalog of Training Courses. The Academy furnished data on the number of students trained in each course in 1978, and the classroom hours. Student labor, per diem cost and travel cost were calculated from these data in accordance with FAA policy and per diem rate. Average travel cost assumed was $250.00 round trip. Recurring academy cost per course for these courses is expected, but has not been received from the academy at the time of writing this report. Therefore, the approximate academy

cost has been estimated. These estimates are partly based upon academy costs received for the Air Traffic courses, and range from $30,000 to $80,000 each annually.

For the computer program, this training cost data is stored separately and handled in the same manner as other reference data, so that it can be revised, extended, etc., without program changes.

This data on student labor cost is regarded as "actual," while the training allowance included in the Maintenance Labor Cost is the standard allowance used for staffing. Obviously, Maintenance Labor Cost includes student labor cost (regardless of the amount), but does not include per diem cost, travel cost, or academy cost. In the summation of automation costs, therefore, student labor cost is not included.

Training cost is incurred on equipment which are not installed or commissioned - ARTS IIIA, ARTS II, DARC, and CD-2- because academy training begins a year or two in advance of first deliveries of new equipment. In addition, there are NAFEC Engineering Support and Software Support costs on new equipment before first delivery. To provide for including these costs, a single entry for each of these equipments has been provided under the heading Future Equipment. For the same reason as above, student labor cost is not included in the summation of automtion cost.

4.5 SPARES. An estimate for purchased spares was derived from a study done by ALG-200. We discovered that in addition to the purchase of spare parts, another major materials cost directly related to this component was in the Exchange and Repair (E&R) program. The ALG study, however,

contained no information on E&R costs. Depot personnel gave the annual cost of the E&R programs as approximately $9.0M, and estimted that automation equipment E&R is at least 30-40%. They also estimated depot labor cost at about $2.0M annually and estimated $0.250M could be allocated to automation. These estimates were accepted since they are the best and only ones available. Therefore, we selected $3.5M as the total automation E&R cost and $0.250M as the total automation depot labor cost for baseline. These are entered only as totals, allocated 80% to enroute and 20% to terminal equipment since we do not know how they are distributed among the types and quantities of automation equipment.

Estimates of spares costs for future equipment were received from the depot by letter dated July 5, 1979. These estimates are in accordance with FAA Order 6011.4 and depot experience and practice.

4.6 TEST EQUIPMENT MAINTENANCE, CALIBRATION, AND REPAIR. Although FAA is developing a national program for test equipment, FAA regions at present have independent programs and practices. At the sites visited, practices ranged from nothing, to use of local laboratories and military bases, to semi-annual visits by mobile facilities contracted for by regions. No specific costs for automation test equipment maintenance, calibration, and repair were obtained. Enroute center maintenance labor estimates for this were from one-half to one man full-time. Therefore, an estimate of 0.35MY for CCC and 0.35MY for CDC/DCC, for a total of 0.7MY for each enroute center was used. Test equipment calibration and repair cost shown as Test Equipment Service was estimated at $3,500 for CCC and for CDC/DCC for a total of $7,000 for each enroute center, and $2,000 for each ARTS III. Similar estimates for the other automation equipment were not attempted since the costs are considered to be very

small.

4.7 SUPPORT ENGINEERING. The Automation Engineering Support Branch (AAF-360) at NAFEC provides hardware support and modification engineering and diagnostic software maintenance for fielded equipment. Organization, personnel assignments, support contract and modification cost data were furnished by (AAF-360). The Automation Systems Division (ARD-100) contribution to continuing engineering support for existing automation systems (basically 9550's) was estimated at five man years of Senior System Analysts (GS 13/14). Specific allocations to equipment are in accordance with current assignments.

4.8 AUTOMATIC DATA INTERCHANGE SYSTEM, SERVICE B. Service B leased costs were obtained for the last three months of 1978 and the first three months of 1979. These quarterly costs were added and multiplied by two to obtain an estimate of annual cost. This cost is handled as a total only, allocated totally to enroute equipment.

4.9 FIELD SOFTWARE MAINTENANCE. Air Traffic software personnel are located at each enroute center and ARTS III terminal site to support operational software, in case of failure or malfunction, to make changes, and to further develop software applications. Personnel data for all sites were furnished by AAT-500, and specific information was obtained from the Data System Officer (DSO) at each site visited. In accordance with the data received, enroute center software support was estimated at 25MY average, and ARTS III terminal sites at 4MY average. Grade levels, salary and rate tables were developed as described in paragraph 4.1.

4.10 AT TRAINING. AT training courses for software support personnel

were selected from the FAA Catalog of Training Courses. The number of students trained in each course in 1978 and the length of each course was furnished by the Academy. In addition, annual recurring Academy cost (instructor cost) for each course was furnished by the Academy. Using these data, costs were calculated for student labor, per diem, travel cost, and Academy cost. Per diem was allowed for each day of training, weekends, and travel time. Two days travel time was estimated for each student in 1978. Round-trip travel cost was estimated at $250 in 1978. These amounts are based upon cost estimates from the Office of Personnel and Training.

4.11 OPERATIONAL SOFTWARE SUPPORT. AAT-550 at NAFEC provides operational software support for commissioned and future computer equipment. Organization and personnel allowance were furnished by AAT-500. Approximate annual support contract expenditures, furnished by AAT-550, are allocated based on current assignment of personnel.

4.12 NAFEC SUPPORT. Hardware, software, and documentation support for the Engineering Support and Operational Support groups are provided by NAFEC. This includes both facilities and personnel. Support cost data for FY1978 and budget estimates for FY1979, 1980 were furnished by F. Meehan, Chief, Budget Division, ANA-30. These costs are allocated based on cost subtotals to Enroute (67%) and Terminal (33%) equipment.

4.13 REGION COST. Regional responsibility for automation equipment is assigned to a small Airway Facilities (AF) staff group at each regional headquarters. The details of specific assignments differ from region to region, and the groups are not the same size. Generally, they assist in a variety of administrative work and assist in problem solving and

problem analysis. In some ways they act as a liaison with NAFEC, and headquarters. Based upon our visits to four regional offices, an average of six people for automation are allocated to each of the regional offices. Allocation to Terminal (47%) and Enroute (53%) are based on estimates of activity.

Regional responsibility for operational software is assigned to a small Air Traffic (AT) staff at each regional headquarters. Their principal activity is usually to assign and control the software development effort performed by the software personnel at the enroute centers and terminals, and as liaison with the operational software support group at NAFEC. Based on our visits, an average of five people are allocated to software support for each of the regional offices. Allocation to Terminal (44%) and Enroute (56%) are based on AT-500 estimates of activity.

4.14 HEADQUARTERS COST, OPERATIONS AND MAINTENANCE. A small number of headquarters personnel in Airway Facilities and Air Traffic are involved in many aspects of fielded equipment and operational problems. All equipment modifications are developed and/or authorized by headquarters personnel. Daily reports on outages and all major problems are analyzed, resulting in many investigations, reports, directives, etc. Data for these headquarters efforts were furnished by AAF-300 and AAT-500. Thirty-six Airway Facilities positions and ten Air Traffic positions are allocated to automation. Allocation is the same as regional support.

4.15 INSTALLATION/PRECOMMISSIONING COST. The model provides the capability for equipment procurement cost and installation/ precommissioning cost to be entered for future equipment. F&E Procurement cost has not been included in this analysis. Installation/

precommissioning costs entered are given in Table 4-3.

4.16 FUTURE REFINEMENTS. The model includes the capability for entry of various acquisition costs over time to assist in future life cycle cost analyses of various investment alternatives:

- o Advanced Development Cost
- o Hardware Development Cost
- o Software Development Cost
- o Test and Evaluation Cost (include contract cost and GFE)
- o New Equipment Procurement

However, no estimates of these types of acquisition costs have been included within the scope of this study.

TABLE 4-3

Installation/Precommissioning Cost

ARTS II	$55,000 each
ARTS IIIA	75,000 each
DARC	30,000 each
CD-2	20,000 each

SECTION 5

EXTENDED BASELINE ELEMENT ESTIMATES

5.1 INTRODUCTION. The cost model has capability to accept a variety of configuration, parametric and economic data on a year-by-year basis to extend baseline cost estimates for up to twenty years. For the purposes of this study, constraints were arbitrarily imposed to bound the study scope. The major changes in the year-to-year estimates are based on currently planned and scheduled facility changes including: 1) implementation of 68 specific ARTS II sites, 2) installation of DARC at the 20 ARTCC's, 3) conversion of all (65) ARTS III systems to ARTS IIIA, and 4) provision for CD-2 equipment at 122 ARSR sites.

The following sections detail extensive criteria for each major element.

5.2 MAINTENANCE LABOR. The current AF Staffing Standards are the basis for extension of all maintenance labor costs. It is assumed that the Staffing Standards will be revised periodically to reflect the changes in status of automation equipment and to reflect changes in maintenance labor standards. This cost model is prepared so that the system configuration and maintenance labor hours can be automatically updated to the current Staffing Standards whenever the program is run. Every new run establishes, in effect, a new baseline, which is a new basis for extrapolation. Therefore, when the final system configuration is reached in 1984 and the Staffing Standards are revised accordingly, this model will be based on the actual configuration and costs as represented by the Staffing Standards -- instead of the schedules and costs estimated at the time the model and report were prepared. The initial program run is based upon the Staffing Standards as of September 30, 1979, and the currently available commissioning schedules and labor estimates.

The present Staffing Standards include estimates for DARC, ARTS IIIA and ARTS II. For DARC and ARTS III the Direct Work estimate in Book 1C is used, but the S&A estimate is not used because the Sector Level S&A allocation to automation will not be affected. For ARTS II both the Direct Work and S&A estimates of Book 1C are used because no basis for allocation of Sector Level S&A to automation is available for these sectors as yet.

CD-2 maintenance labor estimates are not included in the present Staffing Standards. The new units are representative of present technology and, therefore, may require less maintenance effort. On the other hand, they are active redundant units which contain the equivalent of two of the older units and, therefore, may require more effort. They will be located at remote ARSR sites currently manned by a crew of eight. In consideration of these factors, and the constraint that we are not to consider changes in maintenance practice, we have assumed that the current Staffing Standards allowances will apply to similar new units.

5.3 SITE SUPPORT. Site environmental support labor will remain the same as in baseline for CCC, CDC, DCC, and ARTS III. No increase is required for the addition of DARC at enroute centers or for the replacement of ARTS III by ARTS IIIA. Site support labor for ARTS II is estimated at one-half man year annually.

Site support energy will remain the same as in baseline for CCC, CDC, DCC, ARTS III. ARTS IIIA will require an increase of 75 percent over ARTS III to 1.287 MKWH annually. ARTS II at 7 KVA will require 55188 KWH and DARC at 20 KVA will require 158000 KWH.

The baseline rate of $0.04 per KWH has been used. Since the rate is expected to increase significantly in the future, and more exact site support energy requirements for each equipment may be obtained, the above data are accessible in a card file so that it may be revised without making any program changes. The program will also handle a variable rate if desired.

5.4 AF TRAINING. As explained in Paragraph 4.4, the cost of student labor is included in the cost element Maintenance Labor, because staffing practice is based (partly) on the training allowances, not actual training. However, student labor cost is shown as part of the AF and AT Training Cost elements, so that the total annual automation training cost is available. This cost is significantly greater than the training allowance on automation equipment in 1979 (and will continue at a high level through 1982) because of the training requirements on new equipment and because personnel are being trained up to 18 months in advance of delivery of the new automation equipment while the available allowance is mostly used up for the sustaining level of training on existing equipment.

The sustaining level of 1979 training courses and students will be held constant for the extended baseline on CCC, CDC, DCC, RBDPE, and FDEP. The 1979 level of training on ARTS II will be retained through December 1980, and on ARTS IIIA through September 1982 when they will be reduced to the training allowance. ARTS III and CD training costs will drop out as they are replaced by ARTS IIIA and CD-2. DARC and CD-2 estimates were furnished by Academy personnel.

Travel and per diem costs increased in 1979 as a result of the FASTA agreement which affected travel rules. Travel cost is increased from

$250.00 per round trip to $350.00, and per diem from two days per round trip to five days per round trip, plus the number of days at the Academy for each course. These cost increases were introduced because they represent real cost increases in 1978 dollars as a result of a binding labor agreement (not inflation). These estimates were furnished by the Office of Personnel and Training and have been held constant for the remainder of the extended baseline.

5.5 SPARES. The baseline estimates have been used for the baseline equipment in the extended baseline. As the new equipment is commissioned, the spares cost of the new equipment is added. Spares estimates for the new equipment were furnished by the Depot:

CD-2:	$ 8,084
ARTS IIIA:	$27,289
ARTS II:	$ 9,147
DARC:	$30,298

5.6 TEST EQUIPMENT MAINTENANCE. Test equipment labor and service costs for CCC, CDC, DCC, and ARTS III are held constant. ARTS IIIA test equipment cost is assumed the same as ARTS III. Test equipment maintenance cost estimates for other automation equipments are not available and are assumed to be low enough that they are not significant.

5.7 ENGINEERING SUPPORT. Hardware and software support labor and modification costs are redistributed in the first three years of the extended baseline as ARTS III is replaced with ARTS IIIA and ARTS II is commissioned. No change is anticipated in the other engineering support costs - contracts and RD&E support.

5.8 AUTOMATIC DATA INTERCHANGE SYSTEM, SERVICE B. No change in cost of Service B is anticipated, pending the availability of the NADIN system.

5.9 FIELD SOFTWARE MAINTENANCE. Enroute software staff reductions of two positions in three years, and two more positions by 1983 are anticipated. All ARTS III/IIIA software support staff will be three positions when ARTS IIIA's are commissioned. One position (DSS) is added for each ARTS II commissioned, and nine for each EARTS commissioned. These estimates are based upon data provided by AAT-500.

5.10 AF TRAINING. Student levels for courses on the new automation equipments are retained at the 1979 level or as planned by the FAA Academy, until all new equipment is commissioned. After commissioning, student levels are reduced to the staffing standard training allowances.

5.11 OPERATIONAL SOFTWARE SUPPORT. No change in the staff of AAT-550 is anticipated. The number of personnel assigned to each type of automation equipment is shifted as ARTS IIIA and ARTS II are commissioned.

5.12 NAFEC SUPPORT. Estimates provided by ANA-30 are used for FY 1979 and FY 1980, and retained at the FY 1980 level in subsequent years.

5.13 REGION COST. Regional AF automation staff is increased by one position in 1980 in anticipation of the additional support needed for ARTS II and DARC. No change is anticipated in regional AT Automation staff.

5.14 HEADQUARTERS COST, OPERATIONS, AND MAINTENANCE. No increase in Headquarters AF and AT staffs is anticipated.

5.15 INSTALLATION/PRECOMMISSIONING COST. Installation/precommissioning cost estimates for new equipment are given in Table 4-3. Provision is made for entering new equipment procurement cost at some future time, but no estimates are included in this analysis.

5.16 ACQUISITON COST. Provision is made for entering advanced development cost, hardware development cost, software development cost, test and evaluation cost, and equiment procurement cost estimates at some future time, but no estimates are included in this analysis.

SECTION 6

COST ELEMENT SUMMARIES

6.1 INTRODUCTION. For the purpose of data presentation, computer generated cost element estimates have been prepared in three formats. The data is based on an initial set of baseline data initially prepared for FY 1978. Subsequently, the baseline data was updated to reflect FY 1979. The FY 1979 baseline year was then extrapolated assuming constant dollars for the period through 1990. In effect, since the last system configuration change for the purposes of this study are in 1984, annual totals are constant beyond that period.

Included in this section are cost element summaries as follows:

a. Cost category summaries for all automation for the years 1978, 1979 and 1980 presented as labor, material and services.

b. Facility summary reports for each year from 1979-1984 presented in labor, material and services categories.

6.2 AUTOMATION COST SUMMARY. The Automation Cost Summary (figure 6-1) summarizes labor, material and services cost data for the years 1978-1980.

The FY 1978 baseline data was generated during an initial verification of the computer cost model, based on the then most current information. Subsequently, the baseline data was changed to reflect actual operation during FY 1979 with planned configuration changes used as a basis for extrapolating cost through 1990. The FY 1980 summary is the first of the extended baseline years. It must be clearly understood that changes in cost estimates for extended baseline years are solely the result of

planned configuration and staffing level changes for those years. Configuration changes are based solely upon currently approved and budgeted F&E equiment procurement programs and do not include programs which are still within the development phase.

The percentage figures shown on figure 6-1 reflect the annual change in specific categories. For example, total labor increases by 9.1% from 1978 to 1979 and by 4.1% from 1979 to 1980. This illustrates the point that the baseline data for 78 and 79 is based on pay rates applicable to those specific years. The 1979 rates are used without inflation in subsequent extension years which is consistent with the premise of estimating costs in current year (1979) undiscounted dollars. Thus, the change in total labor cost from 1979 to 1980 is solely due to increased AF staff requirements for the additional equipment installed in that period.

Figure 6-2 presents FY 1979 baseline data to show how the automation costs are distributed between major cost categories based on enroute/terminal breakdowns. (Any minor differences between amounts in figure 6-1 and 6-2 are due to round-off variations.) Note that 82% of the total automation maintenance and support cost is attributed to labor. Figures 6-3 through 6-8 are summaries of annual automation cost as follows:

Automation Maintenance and Support Costs

Figure	Fiscal Year
6-3	1979
6-4	1980
6-5	1981
6-6	1982
6-7	1983
6-8	1984

AUTOMATION COST SUMMARY

CATEGORY DESCRIPTION	1978 BASELINE	1979 BASELINE	1980 EXTENDED
A. LABOR COSTS			
1. AF LABOR			
A. FIELD MAINTENANCE			
1) TECHNICIAN DIRECT	$ 25,648	$ 28,533	$ 31,199
2) SUPERVISION & ADMIN.	34,557	38,240	38,592
3) SITE SUPPORT	5,659	6,141	6,543
SUBTOTAL	65,864	72,914	76,334
B. ENGINEERING SUPPORT & MGMT.			
1) NAFEC HARDWARE SUPPORT	1,219	1,307	1,268
2) NAFEC SOFTWARE SUPPORT	1,182	1,265	1,243
3) REGIONS	2,061	2,176	2,538
4) HEADQUARTERS	1,216	1,285	1,323
SUBTOTAL	5,678	6,033	6,372
TOTAL AF LABOR	$ 71,542	$ 78,947 (10.4%)	$ 82,706 (4.8%)
2. AT LABOR			
A. FIELD SOFTWARE SUPPORT	22,857	23,936	24,984
B. NAFEC SOFTWARE SUPPORT	3,406	3,683	3,459
C. REGIONS	1,953	2,062	2,062
D. HEADQUARTERS	328	346	346
TOTAL AT LABOR	$ 27,953	$ 30,027 (7.4%)	$ 30,851 (2.7%)
3. OTHER LABOR			
A. ACADEMY			
1) AF TRAINING	2,555	2,547	2,490
2) AT TRAINING	364	361	345
B. DEPOT SUPPORT*	250	250	250
C. PDEF SUPPORT	176	186	186
TOTAL OTHER LABOR	3,345	3,244	3,271
TOTAL LABOR	$102,840	$112,218 (9.1%)	$116,828 (4.1%)
B. MATERIAL COSTS			
1. SPARE PARTS			
A) PURCHASED SPARES	4,483	4,706	5,214
B) F&P PROGRAM	3,500	3,750	3,750
2. MODIFICATION KITS	237	238	237
TOTAL MATERIAL	$ 8,220	$ 8,694 (11.2%)	$ 9,201 (5.8%)
C. SERVICES COSTS			
1. SITE ENERGY	4,162	4,236	4,554
2. NAFEC COSTS			
A) AF SUPPORT CONTRACTS	2,136	940	940
B) AT SUPPORT CONTRACTS	822	930	930
C) FACILITY SUPPORT	4,900	5,622	6,504
D) DOCUMENTATION SUPPORT	728	848	981
3. DATA COMMUNICATIONS	658	746	746
4. ACADEMY TRAINING			
A) PER DIEM	1,829	1,939	1,902
B) TRAVEL	366	516	506
5. TEST EQUIPMENT	268	297	362
TOTAL SERVICES	$ 15,869	$ 16,074 (1.3%)	$ 17,425 (8.4%)
GRAND TOTAL	$126,929	$136,986 (7.9%)	$143,454 (4.7%)

(%) PERCENT INCREASE FROM PREVIOUS YEAR

FIGURE 6-1

AUTOMATION COST SUMMARY
FY1979 BASELINE

CATEGORY DESCRIPTION	ENROUTE COST		% CATEGORY	TERMINAL COST		% CATEGORY	TOTAL COST	% TOTAL	
A. LABOR COSTS									
1 AF LABOR									
a FIELD MAINTENANCE									
1) TECHNICIAN DIRECT	16,207			12,326					
2) SUPERVISION & ADMINISTRATION	18,223			20,017					
3) SITE SUPPORT	3,846			2,295					
SUB-TOTAL AF LABOR		38,276			34,638				
b ENGINEERING SUPPORT									
1) NAFEC HARDWARE SUPPORT	1,804			503					
2) NAFEC SOFTWARE SUPPORT	871			394					
SUB-TOTAL ENGRG SUPPORT		1,675			897				
c ALLOCATED LABOR COSTS									
1) REGIONS	1,153			1,023					
2) HEADQUARTERS	681			604					
SUB-TOTAL ALLOCATED AF LABOR		1,834			1,627				
TOTAL AF LABOR		41,785	53%		37,162	47%	78,947	70%	
2 AT LABOR									
a DIRECT SYSTEMS SUPPORT									
1) FIELD SOFTWARE SUPPORT	15,338			8,598					
2) NAFEC SOFTWARE SUPPORT	2,274			1,409					
SUB-TOTAL DIRECT SYSTEMS SUPPORT		17,612			10,007				
b ALLOCATED LABOR COSTS									
1) REGIONS	1,155			901					
2) HEADQUARTERS	194			157					
SUB-TOTAL ALLOCATED AT LABOR		1,349			1,059				
TOTAL AT LABOR		18,961	63%		11,066	37%	30,027	27%	
3 OTHER LABOR									
a DIRECT SYSTEMS SUPPORT									
1) AF ACADEMY/INSTRUCTORS	1,622			925					
2) AT ACADEMY/INSTRUCTORS	179			182					
SUB-TOTAL DIRECT SYSTEMS SUPPORT		1,801			1,007				
b ALLOCATED OTHER LABOR COSTS									
1) ENGINEERING SUPPORT (SEDS)	186			0					
2) DEPOT SUPPORT	155			95					
SUB-TOTAL ALLOCATED OTHER LABOR		341			95				
TOTAL OTHER LABOR		2,142			1,102		3,244	3%	
TOTAL LABOR COSTS		62,888	56%		49,330	44%	112,218	100%	82%
B. MATERIAL COSTS									
1 DIRECT MATERIAL COSTS									
a SPARE PARTS	3,648			1,058					
b MODIFICATION KITS	231			7					
SUB-TOTAL DIRECT MATERIAL COSTS		3,879			1,065		4,944	63%	
2 ALLOCATED MATERIAL COSTS									
a EXCHANGE & REPAIR PROGRAM	3,000	3,000		750	750		3,750	37%	
TOTAL MATERIAL COSTS		6,879	69%		1,815	31%	8,694	100%	6%
C. SERVICE COSTS									
1. DIRECT SERVICES COSTS									
a SITE ENERGY	2,309			1,927					
b ACADEMY TRAINING									
1) PER DIEM	884			1,055					
2) TRAVEL	245			271					
c TEST EQUIPMENT SUPPORT	143			154					
SUB-TOTAL DIRECT SERVICES COSTS		3,581			3,407		6,988	43%	
2. ALLOCATED SERVICES COSTS									
a NAFEC COSTS									
1) AF SUPPORT CONTRACTS	620			370					
2) AT SUPPORT CONTRACTS	620			310					
3) FACILITIES SUPPORT	3,748			1,874					
4) DOCUMENTATION SUPPORT	565			283					
SUB-TOTAL NAFEC COSTS		5,553			2,787		8,340	52%	
b DATA COMMUNICATION	746	746		0	0		746		
SUB-TOTAL ALLOCATED SERVICES COSTS								5%	
TOTAL SERVICES COSTS		9,880	61%		6,194	39%	16,074	100%	12%
TOTAL ALL COSTS		79,647	58%		57,339	42%	136,986	--	100%

FIGURE 6-2

AUTOMATION MAINTENANCE & SUPPORT COSTS FOR FISCAL YEAR 1979

CATEGORY DESCRIPTION	ENROUTE: ARTCC: CCC	ARTCC: DISPLAY CHANNEL	ARTCC: DARC	TOTAL ARTCC	C D	EARTS	TOTAL PER CATEGORY	TOTAL EN-ROUTE	TERMINAL: ARTS 3	ARTS 2	BRITE	FDEP	TOTAL PER CATEGORY	TOTAL TERMINAL
A LABOR COSTS														
1 AF LABOR														
a FIELD MAINTENANCE														
1) TECHNICIAN DIRECT	5014	7223	0	12237	3643	327	16207		6443	944	1658	3281	12326	
2) SUPERVISION & ADMINISTRATION	8224	8224	0	16448	1476	259	18223		17619	397	672	1329	20017	
3) SITE SUPPORT	1906	1906	0	3812	0	34	3846		2123	172	0	0	2295	
SUB TOTAL AF LABOR								38276						34638
b ENGINEERING SUPPORT														
1) NAFEC HARDWARE SUPPORT	231	268	302	801	0	3	804		319	184	0	0	503	
2) NAFEC SOFTWARE SUPPORT	298	571	0	869	0	2	871		261	133	0	0	394	
SUB TOTAL ENGRG SUPPORT								1675						897
c ALLOCATED LABOR COSTS														
1) REGIONS							1153						1023	
2) HEADQUARTERS							681						604	
SUB TOTAL ALLOCATED AF LABOR								1834						1627
TOTAL AF LABOR								41785						37162
2 AT LABOR														
a DIRECT SYSTEMS SUPPORT														
1) FIELD SOFTWARE SUPPORT	15047	0	0	15047	0	291	15338		8151	447	0	0	8598	
2) NAFEC SOFTWARE SUPPORT	2261	0	0	2261	0	13	2274		767	642	0	0	1409	
SUB TOTAL DIRECT SYSTEMS SUPPORT								17612						10007
b ALLOCATED LABOR COSTS														
1) REGIONS							1155						907	
2 HEADQUARTERS							194						152	
SUB-TOTAL ALLOCATED AT LABOR								1349						1059
TOTAL AT LABOR								18961						11066
3 OTHER LABOR														
a DIRECT SYSTEMS SUPPORT														
1) AF ACADEMY/INSTRUCTORS	780	660	0	1440	62	120	1622		765	160	0	0	825	
2) AT ACADEMY/INSTRUCTORS	177	0	0	177	0	2	179		220	72	0	0	182	
SUB-TOTAL DIRECT SYSTEMS SUPPORT								1801						1007
b ALLOCATED OTHER LABOR COSTS														
1) ENGINEERING SUPPORT (SRDS)							186						0	
2) DEPOT SUPPORT							155						95	
SUB-TOTAL ALLOCATED OTHER LABOR								341						95
TOTAL OTHER LABOR								2142						1102
TOTAL LABOR COSTS								62888						49330
B MATERIAL COSTS														
1 DIRECT MATERIAL COSTS														
a SPARE PARTS	1368	935	0	2304	1336	8	3648		545	128	0	385	1058	
b MODIFICATION KITS	168	57	0	225	5	0	231		5	2	0	0	7	
SUB-TOTAL DIRECT MATERIAL COSTS								3879						1065
2 ALLOCATED MATERIAL COSTS														
a EXCHANGE & REPAIR PROGRAM							3000	3000					750	750
TOTAL MATERIAL COSTS								6879						1815
C SERVICE COSTS														
1 DIRECT SERVICES COSTS														
a SITE ENERGY	1140	1140	0	2280	0	29	2309		1896	31	0	0	1927	
b ACADEMY TRAINING														
1) PER DIEM	500	325	0	825	20	39	884		582	462	0	11	1055	
2) TRAVEL	141	71	0	212	10	23	245		176	89	0	6	271	
c TEST EQUIPMENT SUPPORT	70	71	0	141	0	2	143		126	28	0	0	154	
SUB-TOTAL DIRECT SERVICES COSTS								3581						3407
2 ALLOCATED SERVICES COSTS														
a NAFEC COSTS														
1) AF SUPPORT CONTRACTS							620						320	
2) AT SUPPORT CONTRACTS							620						310	
3) FACILITIES SUPPORT							3748						1874	
4) DOCUMENTATION SUPPORT							565						283	
SUB TOTAL NAFEC COSTS								5553						2787
b DATA COMMUNICATION							746						0	
SUB-TOTAL ALLOCATED SERVICES COSTS								746						
TOTAL SERVICES COSTS								9880						6194
TOTAL ALL COSTS								79647						57339

NOTE: Amounts indicated are $1,000 increments.

FIGURE 6-3

AUTOMATION MAINTENANCE & SUPPORT COSTS FOR FISCAL YEAR 1980

CATEGORY DESCRIPTION	ENROUTE: ARTCC: CCC	ENROUTE: ARTCC: DISPLAY CHANNEL	ENROUTE: ARTCC: DARC	ENROUTE: TOTAL ARTCC	ENROUTE: C D	ENROUTE: EARTS	ENROUTE: TOTAL PER CATEGORY	TOTAL EN-ROUTE	TERMINAL: ARTS 3	TERMINAL: ARTS 2	TERMINAL: DBRPE	TERMINAL: FDEP	TERMINAL: TOTAL PER CATEGORY	TOTAL TERMINAL
A LABOR COSTS														
1 AF LABOR														
a FIELD MAINTENANCE														
1) TECHNICIAN DIRECT	5014	7224	0	12237	3643	327	16207		6926	3137	1648	3281	14992	
2) SUPERVISION & ADMINISTRATION	8224	8224	0	16448	1476	299	18223		17072	1300	668	1329	20369	
3) SITE SUPPORT	1906	1906	0	3812	0	34	3846		2122	575	0	0	2697	
SUB TOTAL AF LABOR								38276						38058
b ENGINEERING SUPPORT														
1) NAFEC HARDWARE SUPPORT	231	268	302 *	801	0 *	3	804		280	184	0	0	464	
2) NAFEC SOFTWARE SUPPORT	298	571	0 *	869	0	2 *	871		239	133	0	* 0	372	
SUB TOTAL ENGRG SUPPORT								1675						836
c ALLOCATED LABOR COSTS														
1) REGIONS							1345						1193	
2) HEADQUARTERS							719						604	
SUB TOTAL ALLOCATED AF LABOR								2064						1797
TOTAL AF LABOR								42015						40691
2 AT LABOR														
a DIRECT SYSTEMS SUPPORT														
1) FIELD SOFTWARE SUPPORT	15047	0	0	15047	0	291	15338		8151	1496	0	0	9647	
2) NAFEC SOFTWARE SUPPORT	1870	0	0	1870	0	9	1879		1021	558	0	0	1579	
SUB TOTAL DIRECT SYSTEMS SUPPORT								17217						11226
b ALLOCATED LABOR COSTS														
1) REGIONS							1155						907	
2 HEADQUARTERS							194						152	
SUB TOTAL ALLOCATED AT LABOR								1349						1059
TOTAL AT LABOR								18566						12285
3 OTHER LABOR														
a DIRECT SYSTEMS SUPPORT														
1) AF ACADEMY / INSTRUCTORS	780	660	0	1440	62	120	1622		708	160	0	0	868	
2) AT ACADEMY / INSTRUCTORS	177	0	0	177	0	2	179		94	72	0	0	166	
SUB TOTAL DIRECT SYSTEMS SUPPORT								1801						1034
b ALLOCATED OTHER LABOR COSTS														
1) ENGINEERING SUPPORT (SEOS)							186						0	
2) DEPOT SUPPORT							175						75	
SUB TOTAL ALLOCATED OTHER LABOR								361						75
TOTAL OTHER LABOR								2162						1109
TOTAL LABOR COSTS								62743						54085
B. MATERIAL COSTS														
1 DIRECT MATERIAL COSTS														
a SPARE PARTS	1368	936	0	2304	1336	8	3648		758	424	0	384	1566	
b MODIFICATION KITS	168	58	0	226	5	0	231		4	2	0	0	6	
SUB TOTAL DIRECT MATERIAL COSTS								3879						1572
2 ALLOCATED MATERIAL COSTS														
a EXCHANGE & REPAIR PROGRAM							3000	3000					750	750
TOTAL MATERIAL COSTS								6879						2322
C. SERVICE COSTS														
1 DIRECT SERVICES COSTS														
a SITE ENERGY	1140	1140	0	2280	0	29	2309		2141	104	0	0	2245	
b ACADEMY TRAINING	500	325	0	825	20	39	884		545	462	0	11	1018	
1) PER DIEM	142	71	0	213	10	23	246		165	89	0	6	260	
2) TRAVEL	70	70	0	140	0	2	142		126	94	0	0	220	
c. TEST EQUIPMENT SUPPORT														
SUB TOTAL DIRECT SERVICES COSTS								3581						3743
2 ALLOCATED SERVICES COSTS														
a NAFEC COSTS														
1) AF SUPPORT CONTRACTS							620						320	
2) AT SUPPORT CONTRACTS							620						310	
3) FACILITIES SUPPORT							4336						2168	
4) DOCUMENTATION SUPPORT							654						327	
SUB TOTAL NAFEC COSTS								6230						3125
b DATA COMMUNICATION							746						0	
SUB TOTAL ALLOCATED SERVICES COSTS								746						
TOTAL SERVICES COSTS								10557						6868
TOTAL ALL COSTS								80179						63275

NOTE: Amounts indicated are $1,000 increments.

FIGURE 6-4

AUTOMATIC MAINTENANCE & SUPPORT COSTS FOR FISCAL YEAR 1981

CATEGORY DESCRIPTION	EN ROUTE: ARTCC: CCC	EN ROUTE: ARTCC: DISPLAY CHANNEL	EN ROUTE: ARTCC: DARC	EN ROUTE: TOTAL ARTCC	EN ROUTE: C O	EN ROUTE: EARTS	EN ROUTE: TOTAL PER CATEGORY	TOTAL EN ROUTE	TERMINAL: ARTS 3	TERMINAL: ARTS 2	TERMINAL: BDDPE	TERMINAL: FDEP	TERMINAL: TOTAL PER CATEGORY	TOTAL TERMINAL
A LABOR COSTS														
1 AF LABOR														
a FIELD MAINTENANCE														
1) TECHNICIAN DIRECT	5014	7224	301	12539	3643	327	16509		8258	4442	1648	3281	17629	
2) SUPERVISION & ADMINISTRATION	8224	8224	0	16448	1476	299	18223		16834	1829	668	1329	20660	
3) STAFF SUPPORT	1906	1905	0	3811	0	34	3845		2145	798	0	0	2943	
SUB TOTAL AF LABOR								38577						41232
b ENGINEERING SUPPORT														
1) NAFEC HARDWARE SUPPORT	231	268	302*	801	0*	3	804		203	184	0	0	387	
2) NAFEC SOFTWARE SUPPORT	298	571	0*	869	0	2*	871		193	133	0	0	326	
SUB TOTAL ENGRG SUPPORT								1675						713
c ALLOCATED LABOR COSTS														
1) REGIONS							1345						1193	
2) HEADQUARTERS							719						604	
SUB TOTAL ALLOCATED AF LABOR								2064						1797
TOTAL AF LABOR								42316						43742
2 AT LABOR														
a DIRECT SYSTEMS SUPPORT														
1) FIELD SOFTWARE SUPPORT	13241	0	0	13241	0	291	13532		7083	2077	0	0	9160	
2) NAFEC SOFTWARE SUPPORT	1870	0	0	1870	0	9	1879		1033	558	0	0	1591	
SUB TOTAL DIRECT SYSTEMS SUPPORT								15411						10751
b ALLOCATED LABOR COSTS														
1) REGIONS													907	
2 HEADQUARTERS							194						152	
SUB TOTAL ALLOCATED AT LABOR								1349						1059
TOTAL AT LABOR								16760						11810
3 OTHER LABOR														
a DIRECT SYSTEMS SUPPORT														
1) AF ACADEMY / INSTRUCTORS	780	660	0	1440	61	120	1621		957	411	0	0	1368	
2) AT ACADEMY / INSTRUCTORS	177	0	0	177	0	2	179		62	72	0	0	134	
SUB TOTAL DIRECT SYSTEMS SUPPORT								1800						1502
b ALLOCATED OTHER LABOR COSTS														
1) ENGINEERING SUPPORT (SEDS)							186						0	
2) DEPOT SUPPORT							165						85	
SUB-TOTAL ALLOCATED OTHER LABOR								351						85
TOTAL OTHER LABOR								2151						1587
TOTAL LABOR COSTS								61227						57139
B. MATERIAL COSTS														
1 DIRECT MATERIAL COSTS														
a SPARE PARTS	1368	936	270	2574	1322	8	3904		1198	589	0	384	2171	
b MODIFICATION KITS	168	58	0	226	5	0	231		2	2	0	0	4	
SUB TOTAL DIRECT MATERIAL COSTS								4135						2175
2 ALLOCATED MATERIAL COSTS														
a EXCHANGE & REPAIR PROGRAM							3000	3000					750	750
TOTAL MATERIAL COSTS								7135						2925
C. SERVICE COSTS														
1 DIRECT SERVICES COSTS														
a SITE ENERGY	1140	1140	56	2336	0	29	2365		2659	144	0	0	2803	
b ACADEMY TRAINING														
1) PER DIEM	500	325	0	825	19	39	883		140	76	0	11	227	
2) TRAVEL	142	71	0	213	10	23	246		39	31	0	6	76	
c TEST EQUIPMENT SUPPORT	70	70	0	140	0	2	142		127	131	0	0	258	
SUB TOTAL DIRECT SERVICES COSTS								3636						3364
2 ALLOCATED SERVICES COSTS														
a N A F E C COSTS														
1) AF SUPPORT CONTRACTS							620						320	
2) AT SUPPORT CONTRACTS							620						310	
3) FACILITIES SUPPORT							4336						2168	
4) DOCUMENTATION SUPPORT							654						327	
SUB-TOTAL N A F E C COSTS								6230						3125
b DATA COMMUNICATION							746							
SUB-TOTAL ALLOCATED SERVICES COSTS								746						
TOTAL SERVICES COSTS								10617						6489
TOTAL ALL COSTS								78974						66553

NOTE: Amounts indicated are $1,000 increments.

*See Appendix B for revised numbers.

FIGURE 6-5

AUTOMATION MAINTENANCE & SUPPORT COSTS FOR FISCAL YEAR 1982

CATEGORY DESCRIPTION	ENROUTE: ARTCC: CCC	ARTCC: DISPLAY CHANNEL	ARTCC: DARC	TOTAL ARTCC	C D	EARTS	TOTAL PER CATEGORY	TOTAL EN ROUTE	TERMINAL: ARTS 3	ARTS 2	DBRITE	FDEP	TOTAL PER CATEGORY	TOTAL TERMINAL
A LABOR COSTS														
1 AF LABOR														
a FIELD MAINTENANCE														
1) TECHNICIAN DIRECT	5014	7223	676	12913	3786	327	17026		9546	4606	1648	3281	19081	
2) SUPERVISION & ADMINISTRATION	8224	8224	0	16448	1534	299	18281		16866	1896	668	1329	20759	
3) SITE SUPPORT	1906	1906	0	3812	0	34	3946		2157	827	0	0	2984	
SUB TOTAL AF LABOR								39153						42824
b ENGINEERING SUPPORT														
1) NAFEC HARDWARE SUPPORT	231	268	302*	801	0*	3	804		126	184	0	0	310	
2) NAFEC SOFTWARE SUPPORT	298	571	0*	869	0	2*	871		146	133	0	0	279	
SUB TOTAL ENGRG SUPPORT								1675						589
c ALLOCATED LABOR COSTS														
1) REGIONS							1345						1193	
2) HEADQUARTERS							715						604	
SUB TOTAL ALLOCATED AF LABOR								2060						1797
TOTAL AF LABOR								42888						45210
2 AT LABOR														
a DIRECT SYSTEMS SUPPORT														
1) FIELD SOFTWARE SUPPORT	13241	0	0	13241	0	291	13532		6404	2151	0	0	8555	
2) NAFEC SOFTWARE SUPPORT	1870	0	0	1870	0	9	1879		1033	558	0	0	1591	
SUB TOTAL DIRECT SYSTEMS SUPPORT								15411						10146
b ALLOCATED LABOR COSTS														
1) REGIONS							1155						907	
2 HEADQUARTERS							194						152	
SUB TOTAL ALLOCATED AT LABOR								1349						1059
TOTAL AT LABOR								16760						11205
3 OTHER LABOR														
a DIRECT SYSTEMS SUPPORT														
1) AT ACADEMY/INSTRUCTORS	780	660	0	1440	36	120	1596		843	411	0	0	1254	
2) AT ACADEMY/INSTRUCTORS	177	0	0	177	0	2	179		30	72	0	0	102	
SUB TOTAL DIRECT SYSTEMS SUPPORT								1775						1356
b ALLOCATED OTHER LABOR COSTS														
1) ENGINEERING SUPPORT (SEDS)							186						186	
2) DEPOT SUPPORT							155						93	
SUB TOTAL ALLOCATED OTHER LABOR								341						279
TOTAL OTHER LABOR								2116						1635
TOTAL LABOR COSTS								61764						58050
B MATERIAL COSTS														
1 DIRECT MATERIAL COSTS														
a SPARE PARTS	1368	936	606	2910	1121	8	4039		1631	611	0	384	2626	
b MODIFICATION KITS	168	58	0	226	3	0	229		5	2	0	0	7	
SUB TOTAL DIRECT MATERIAL COSTS								4268						2633
2 ALLOCATED MATERIAL COSTS														
a EXCHANGE & REPAIR PROGRAM							3000	3000					750	750
TOTAL MATERIAL COSTS								7268						3383
C SERVICE COSTS														
1 DIRECT SERVICES COSTS														
a SITE ENERGY	1140	1140	126	2406	0	29	2435		3162	149	0	0	3311	
b ACADEMY TRAINING	500	325	0	825	11	39	875		67	76	0	11	154	
1) PER DIEM	142	71	0	213	6	23	243		22	31	0	6	59	
2) TRAVEL														
c TEST EQUIPMENT SUPPORT	70	70	0	140	0	2	142		128	136	0	0	264	
SUB TOTAL DIRECT SERVICES COSTS								3695						3788
2 ALLOCATED SERVICES COSTS														
a NAFEC COSTS														
1) AF SUPPORT CONTRACTS							620						320	
2) AT SUPPORT CONTRACTS							620						310	
3) FACILITIES SUPPORT							4336						2168	
4) DOCUMENTATION SUPPORT							659						322	
SUB TOTAL NAFEC COSTS								6230						3125
b DATA COMMUNICATION							746						0	
SUB TOTAL ALLOCATED SERVICES COSTS								746						0
TOTAL SERVICES COSTS								10671						6913
TOTAL ALL COSTS								79205						68346

NOTE: Amounts indicated are $1,000 increments.
*See Appendix B for revised numbers.

FIGURE 6-6

AUTOMATION MAINTENANCE & SUPPORT COSTS FOR
FISCAL YEAR 1983

CATEGORY DESCRIPTION	ENROUTE: ARTCC: CCC	ARTCC: DISPLAY CHANNEL	ARTCC: DARC	TOTAL ARTCC	C D	EARTS	TOTAL PER CATEGORY	TOTAL EN ROUTE
A LABOR COSTS								
1 AF LABOR								
a FIELD MAINTENANCE								
1) TECHNICIAN DIRECT	5014	7223	676	12913	4613	327	17853	
2) SUPERVISION & ADMINISTRATION	8224	8224	0	16448	1869	299	18616	
3) SITE SUPPORT	1906	1906	0	3812	0	34	3846	
SUB TOTAL AF LABOR								40315
b ENGINEERING SUPPORT								
1) NAFEC HARDWARE SUPPORT	231	268	302*	801	0*	5	806	
2) NAFEC SOFTWARE SUPPORT	298	571	0*	869	0	2*	871	
SUB TOTAL ENGRG SUPPORT								1675
c ALLOCATED LABOR COSTS								
1) REGIONS							1345	
2) HEADQUARTERS							719	
SUB TOTAL ALLOCATED AF LABOR								2064
TOTAL AF LABOR								44054
2 AT LABOR								
a DIRECT SYSTEMS SUPPORT								
1) FIELD SOFTWARE SUPPORT	12037	0	0	12037	0	291	12328	
2) NAFEC SOFTWARE SUPPORT	1870	0	0	1870	0	9	1879	
SUB TOTAL DIRECT SYSTEMS SUPPORT								14207
b ALLOCATED LABOR COSTS								
1) REGIONS							1155	
2 HEADQUARTERS							907	
SUB TOTAL ALLOCATED AT LABOR								2062
TOTAL AT LABOR								16269
3 OTHER LABOR								
a DIRECT SYSTEMS SUPPORT								
1) AF ACADEMY / INSTRUCTORS	780	660	0	1440	12	120	1572	
2) AT ACADEMY / INSTRUCTORS	177	0	0	177	0	2	179	
SUB TOTAL DIRECT SYSTEMS SUPPORT								1751
b ALLOCATED OTHER LABOR COSTS								
1) ENGINEERING SUPPORT (SEDS)							186	
2) DEPOT SUPPORT							150	
SUB TOTAL ALLOCATED OTHER LABOR								336
TOTAL OTHER LABOR								2087
TOTAL LABOR COSTS								62410
B MATERIAL COSTS								
1 DIRECT MATERIAL COSTS								
a SPARE PARTS	1368	936	606	2910	1047	8	3965	
b MODIFICATION KITS	168	58	0	226	1	0	227	
SUB TOTAL DIRECT MATERIAL COSTS								4192
2 ALLOCATED MATERIAL COSTS								
a EXCHANGE & REPAIR PROGRAM							3000	3000
TOTAL MATERIAL COSTS								7192
C SERVICE COSTS								
1 DIRECT SERVICES COSTS								
a SITE ENERGY	1140	1140	126	2406	0	29	2435	
b ACADEMY TRAINING								
1) PER DIEM	500	325	0	825	4	39	868	
2) TRAVEL	142	71	0	213	2	23	238	
c TEST EQUIPMENT SUPPORT	70	70	0	140	0	2	142	
SUB TOTAL DIRECT SERVICES COSTS								3683
2 ALLOCATED SERVICES COSTS								
a NAFEC COSTS								
1) AF SUPPORT CONTRACTS							620	
2) AT SUPPORT CONTRACTS							620	
3) FACILITIES SUPPORT							4336	
4) DOCUMENTATION SUPPORT							654	
SUB TOTAL NAFEC COSTS								6230
b DATA COMMUNICATION							796	
SUB TOTAL ALLOCATED SERVICES COSTS								796
TOTAL SERVICES COSTS								10659
TOTAL ALL COSTS								80261

CATEGORY DESCRIPTION	TERMINAL: ARTS 3	ARTS 2	RDDPE	FDEP	TOTAL PER CATEGORY	TOTAL TERMINAL
A LABOR COSTS						
1 AF LABOR						
a FIELD MAINTENANCE						
1) TECHNICIAN DIRECT	9742	4620	1648	3281	19291	
2) SUPERVISION & ADMINISTRATION	16716	1901	668	1329	20614	
3) SITE SUPPORT	2157	829	0	0	2986	
SUB TOTAL AF LABOR						42891
b ENGINEERING SUPPORT						
1) NAFEC HARDWARE SUPPORT	107	184	0	0	291	
2) NAFEC SOFTWARE SUPPORT	134	133	0*	0	267	
SUB TOTAL ENGRG SUPPORT						558
c ALLOCATED LABOR COSTS						
1) REGIONS					1193	
2) HEADQUARTERS					604	
SUB TOTAL ALLOCATED AF LABOR						1797
TOTAL AF LABOR						45246
2 AT LABOR						
a DIRECT SYSTEMS SUPPORT						
1) FIELD SOFTWARE SUPPORT	6210	2157	0	0	8367	
2) NAFEC SOFTWARE SUPPORT	1049	558	0	0	1607	
SUB TOTAL DIRECT SYSTEMS SUPPORT						9974
b ALLOCATED LABOR COSTS						
1) REGIONS					194	
2 HEADQUARTERS					152	
SUB TOTAL ALLOCATED AT LABOR						346
TOTAL AT LABOR						10320
3 OTHER LABOR						
a DIRECT SYSTEMS SUPPORT						
1) AF ACADEMY / INSTRUCTORS	825	411	0	0	1236	
2) AT ACADEMY / INSTRUCTORS	22	72	0	0	94	
SUB TOTAL DIRECT SYSTEMS SUPPORT						1330
b ALLOCATED OTHER LABOR COSTS						
1) ENGINEERING SUPPORT (SEDS)						
2) DEPOT SUPPORT					100	
SUB TOTAL ALLOCATED OTHER LABOR						100
TOTAL OTHER LABOR						1430
TOTAL LABOR COSTS						56996
B MATERIAL COSTS						
1 DIRECT MATERIAL COSTS						
a SPARE PARTS	1747	612	0	385	2744	
b MODIFICATION KITS	0	2	0	0	2	
SUB TOTAL DIRECT MATERIAL COSTS						2746
2 ALLOCATED MATERIAL COSTS						
a EXCHANGE & REPAIR PROGRAM					750	750
TOTAL MATERIAL COSTS						3496
C SERVICE COSTS						
1 DIRECT SERVICES COSTS						
a SITE ENERGY	3295	150	0	0	3445	
b ACADEMY TRAINING						
1) PER DIEM	48	76	0	11	135	
2) TRAVEL	18	31	0	6	55	
c TEST EQUIPMENT SUPPORT	128	136	0	0	264	
SUB TOTAL DIRECT SERVICES COSTS						3899
2 ALLOCATED SERVICES COSTS						
a NAFEC COSTS						
1) AF SUPPORT CONTRACTS					320	
2) AT SUPPORT CONTRACTS					310	
3) FACILITIES SUPPORT					2168	
4) DOCUMENTATION SUPPORT					327	
SUB TOTAL NAFEC COSTS						3125
b DATA COMMUNICATION						
SUB TOTAL ALLOCATED SERVICES COSTS						0
TOTAL SERVICES COSTS						7024
TOTAL ALL COSTS						67516

NOTE: Amounts indicated are $1,000 increments.
*See Appendix B for revised numbers,

FIGURE 6-7

AUTOMATION MAINTENANCE & SUPPORT COSTS FOR
FISCAL YEAR 1984

CATEGORY DESCRIPTION	ENROUTE							TOTAL EN-ROUTE	TERMINAL					TOTAL TERMINAL
	ARTCC			TOTAL ARTCC	CD	EARTS	TOTAL PER CATEGORY		ARTS 3	ARTS 2	BRITE	FDEP	TOTAL PER CATEGORY	
	CCC	[illegible]	DARC											
A LABOR COSTS														
1 AF LABOR														
a FIELD MAINTENANCE														
1) TECHNICIAN DIRECT	5014	7223	676	12913	4791	327	18031		9742	4620	1648	3281	19291	
2) SUPERVISION & ADMINISTRATION	8224	8224	0	16448	1941	299	18688		16716	1901	668	1329	20614	
3) SITE SUPPORT	1906	1906	0	3812	0	34	3846		2157	829	0	0	2986	
SUB-TOTAL AF LABOR								40565						42891
b ENGINEERING SUPPORT														
1) NAFEC HARDWARE SUPPORT	231	268	302*	801	0*	3	804		107	184	0	0	291	
2) NAFEC SOFTWARE SUPPORT	298	571	0*	869	0	2*	871		134	133	0	0	267	
SUB-TOTAL ENGRG SUPPORT								1675						558
c ALLOCATED LABOR COSTS														
1) REGIONS							1345						1193	
2) HEADQUARTERS							719						604	
SUB-TOTAL ALLOCATED AF LABOR								2064						1797
TOTAL AF LABOR								44304						45246
2 AT LABOR														
a DIRECT SYSTEMS SUPPORT														
1) FIELD SOFTWARE SUPPORT	12037	0	0	12037	0	291	12328		6210	2157	0	0	8367	
2) NAFEC SOFTWARE SUPPORT	1870	0	0	1870	0	9	1879		1049	558	0	0	1607	
SUB-TOTAL DIRECT SYSTEMS SUPPORT								14207						9974
b ALLOCATED LABOR COSTS														
1) REGIONS							1155						194	
2 HEADQUARTERS							907						152	
SUB-TOTAL ALLOCATED AT LABOR								2062						346
TOTAL AT LABOR								16269						10320
3 OTHER LABOR														
a DIRECT SYSTEMS SUPPORT														
1) AF ACADEMY/INSTRUCTORS	780	660	0	1440	8	120	1568		825	411	0	0	1236	
2) AT ACADEMY/INSTRUCTORS	177	0	0	177	0	2	179		22	72	0	0	94	
SUB-TOTAL DIRECT SYSTEMS SUPPORT								1747						1330
b ALLOCATED OTHER LABOR COSTS														
1) ENGINEERING SUPPORT (SRDS)							186							
2) DEPOT SUPPORT							150						100	
SUB-TOTAL ALLOCATED OTHER LABOR								336						100
TOTAL OTHER LABOR								2083						1430
TOTAL LABOR COSTS								62656						56996
B. MATERIAL COSTS														
1 DIRECT MATERIAL COSTS														
a SPARE PARTS	1368	936	606	2910	1051	8	3969		1747	612	0	385	2744	
b MODIFICATION KITS	168	58	0	226	1	0	227		0	2	0	0	2	
SUB-TOTAL DIRECT MATERIAL COSTS								4196						2746
2 ALLOCATED MATERIAL COSTS														
a EXCHANGE & REPAIR PROGRAM							3000	3000					750	750
TOTAL MATERIAL COSTS								7196						3496
C. SERVICE COSTS														
1 DIRECT SERVICES COSTS														
a SITE ENERGY	1140	1140	126	2406	0	29	2435		3295	150	0	0	3445	
b ACADEMY TRAINING														
1) PER DIEM	500	325	0	825	3	39	867		48	76	0	11	135	
2) TRAVEL	142	71	0	213	1	23	237		18	31	0	6	55	
c TEST EQUIPMENT SUPPORT	70	70		140	0	2	142		128	136	0	0	264	
SUB-TOTAL DIRECT SERVICES COSTS								3681						3899
2 ALLOCATED SERVICES COSTS														
a NAFEC COSTS														
1) AF SUPPORT CONTRACTS							620						320	
2) AT SUPPORT CONTRACTS							620						310	
3) FACILITIES SUPPORT							4336						2168	
4) DOCUMENTATION SUPPORT							654						327	
SUB-TOTAL NAFEC COSTS								6230						3125
b DATA COMMUNICATION							746							
SUB-TOTAL ALLOCATED SERVICES COSTS								746						0
TOTAL SERVICES COSTS								10657						7024
TOTAL ALL COSTS								80509						67516

NOTE: Amounts Indicated are $1,000 Increments.
*See Appendix B for revised numbers.

FIGURE 6-8

SECTION 7

CONCLUSIONS

7.0 GENERAL. This study has resulted in a better base of understanding of the costs associated with support of automation systems in the agency environment. As had been anticipated, the most significant cost drivers are related to personnel requirements. The safety, reliability and system management requirements imposed by the geographic dispersion of multiple system configurations providing operational support on a 7 day-a-week, nearly 24 hour-a-day schedule, generate needs for large numbers of properly trained personnel at a number of operational and support locations.

The methodology developed for cost estimating could be further refined and perhaps simplified; however, it is felt that provision has been made to handle the significant cost drivers for system maintenance and support.

7.1 OBSERVATIONS AND RECOMMENDATIONS. This study has provided an almost unprecedented opportunity for the participants to observe a wide variety of FAA organizations; their personnel, operations, and procedures. The level of concern and the dedication of personnel, at all levels, for the proper operation and support of the NAS system is unique in our experience. In part, we feel that this is due to the fact that the vast majority of support personnel have had the opportunity to grow with the system as it evolved and can continue to see evolution and growth in the future. As the system continues to grow in complexity and as new people are added to the support staff, additional systems specialists will be required. At the same time, future systems will have enhanced automation

support subsystems for fault diagnosis, trouble-shooting and repair. Careful consideration must be given to the training of the future system specialists at the site level for both hardware and software.

7.1.1 PERSONNEL REPLACEMENT. In general, the observation can be made that the average age of systems specialists tends to be about the same. It sould be anticipated that the need will arise to provide replacements for the current system specialists over a relatively short time interval of three to five years within the next ten to fifteen years. This will have implications on the cost of training, both formal and on-the-job during that period.

7.1.2 SPARES COST. The ability to identify and track spares cost related to a specific equipment is currently not supported by the administrative system. The system should be enhanced or modified to enable the depot to identify the total number of spare parts and the equipment on which they are used. In addition, provisions for relating computer parts usage with component part failures should be established.

A more efficient communication network from the FAA Technical Center to the FAA depot would lead to more effective transmission of usage and failure trend information. This improvement would enhance the agency's ability to obtain maximum benefit from the information it gathers on spare parts.

A system that disseminates spares information more effectively and more efficiently should enable the depot to improve its overall budgeting and planning process, especially decisions affecting the level of spares inventory to keep on hand, and also in choosing the most efficient

reorder cycle.

7.1.3 SOFTWARE SUPPORT COST. Software support will become of increasing significance in future equipments. Clear differentiation between systems, applications, adaptation and diagnostic software and the support requirements for each must be better understood and controlled by the agency. Future systems must be adequately supported with verification and validation methodologies using system simulations that do not rely on operational sites for validation prior to release.

Current practices related to software distribution of system releases and patches should be reviewed to minimize requirements for site personnel and system usage.

7.2 COST MODEL IMPROVEMENTS. The AUTO/ECON cost model can be effectively utilized in its present form. Two areas of improvement should be considered.

The internal handling of training cost estimates should be simplified to minimize the need to handle large volumes of course level data. The current implementation of cost estimating for individual courses could be refined to a substantial degree.

The report writer portion of the program could be significantly simplified to present only a single data format similar to figures 6-4 through 6-9 of this report. Also, if the report writer portion of the program is modified substantially, the Office of Aviation Policy and Plans should consider waiving the mandate that it be programmed using the FORTRAN IV language. Instead, it is recommended that the report writer

portion be programmed in COBOL or some other widely supported programming language which is more efficient for these types of applications.

Appendix A

AUTOMATION SYSTEMS DESCRIPTIONS

A-1.0 INTRODUCTION. In order to provide a general understanding of the systems and their functions, the following paragraphs describe each data processing and display system, FDEP and CD. Figure A-1 illustrates the relationship between elements of the NAS air traffic control automation systems.

A-2.0 ENROUTE SYSTEMS. Enroute Air Traffic Control (ATC) systems provide for direction of air traffic above certain altitudes, over the continental U.S. (CONUS), and assigned ocean areas. As aircraft reach the boundary on one enroute system control space, they come under the direction of an adjacent enroute control space or a terminal control space. In 1979 there were 20 enroute automation systems and enroute control centers in the continental U.S. (CONUS), and one automation system at Anchorage, Alaska. The 20 CONUS systems have similar equipment; and IBM central processor, and either Raytheon or IBM display computer and displays. These facilities are referred to as Air Route Traffic Control Centers (ARTCC). The Alaska system has an Automated Radar Terminal System (ARTS) modified for use as an Enroute Automated Radar Tracking System (EARTS). Three additional EARTS will be commissioned in 1979. Air Traffic Controllers are in radio contact with aircraft under their direction, and have telephone contact with other controllers.

A-2.1 AIR ROUTE TRAFFIC CONTROL CENTER (ARTCC). Figure A-2 provides a simplified diagram of an ARTCC automation system. The diagram does not depict all of the equipment at an ARTCC, but only the principal equipment

which relate directly to the automation equipment.

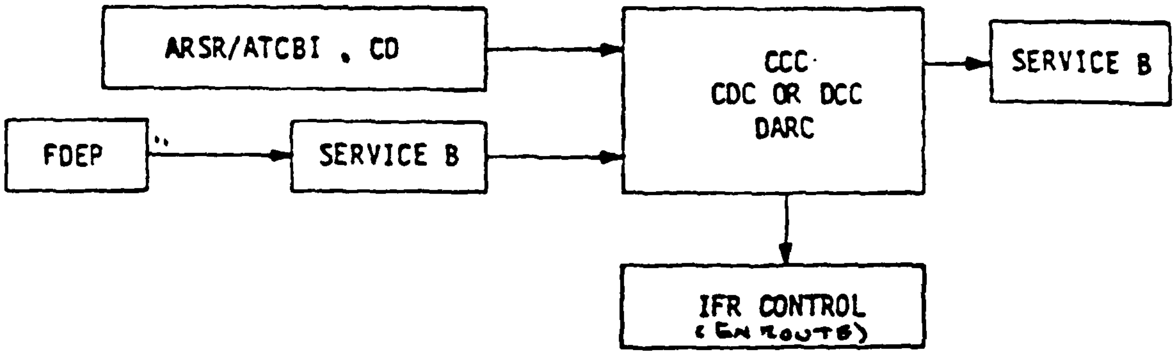
Several long range (200 miles) Radar/Beacon systems are used to monitor the air space controlled by each ARTCC. Radar video (analog) data passes through the Data Receiver Group (DRG) and bypasses the computer system, but digital data from radars and beacons enters the Central Computer Complex (CCC). The CCC is programmed to perform the functions necessary to identify, correlate, sort, select, and format the aircraft identification and position data for further processing by either a Computer Display Channel (CDC) or a Display Channel Complex (DCC). Operational software controls the functions of the CDC/DCC. The Flight Strip Printers (FSP) provide preflight plan information, updated during flight for changes or delays, via FDEP and Service B.

The Display Generator Equipment (DGE) is included in the CDC, but is a separate unit in the DCC configuration. It provides the interface between the computer systems and the Plan View Display (PVD) during normal operations, and between the broadband or the Direct Access Radar Channel (DARC) system, and the PVD's in the backup operational mode.

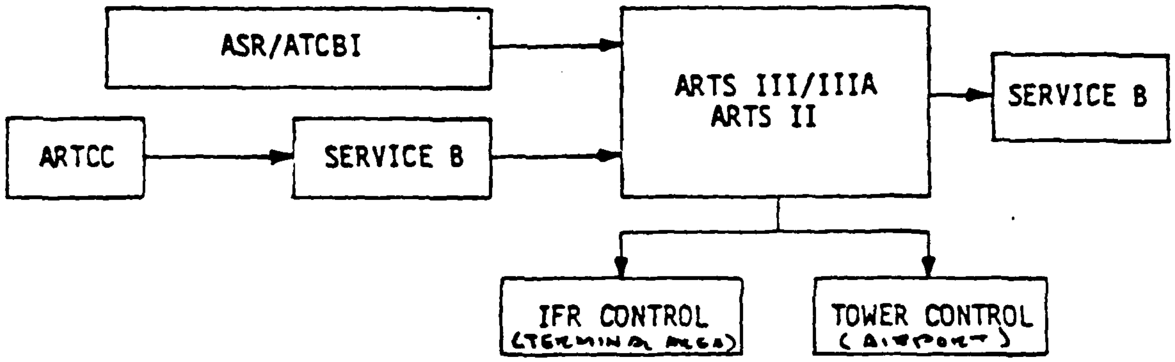
The current broadband backup operational mode provides raw radar data to the displays, without alphanumeric data to identify the aircraft. The broadband replacement system, DARC, should be commissioned at all enroute centers by July 1981. The DARC is an active redundant computer system that will provide radar and beacon location data and beacon alphanumeric aircraft identification to the displays in the backup operational mode.

The enroute computer and display systems are referred to as 9020A, 9020D, and 9020D/E systems. Figure A-3 indicates the configuration of each of

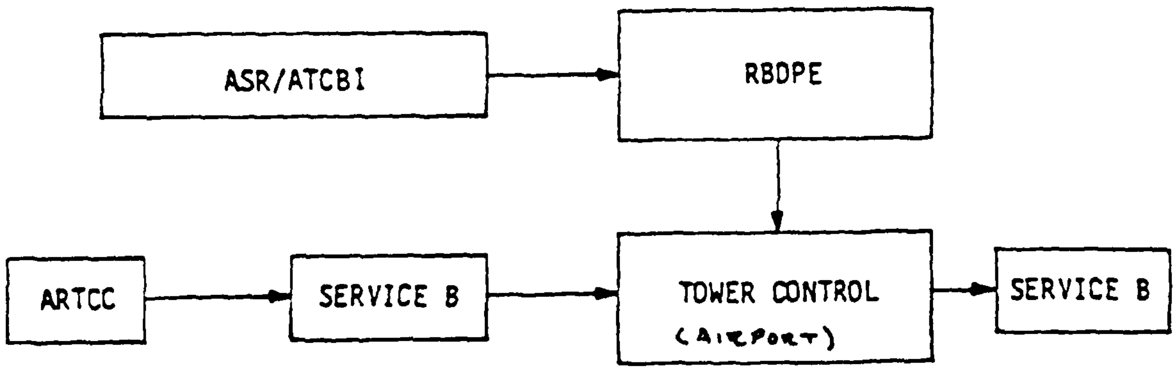
ENROUTE CENTER (ARTCC)



TERMINAL CENTER: (TRACON) (RAPCON) (RATCF) (TRACAB)



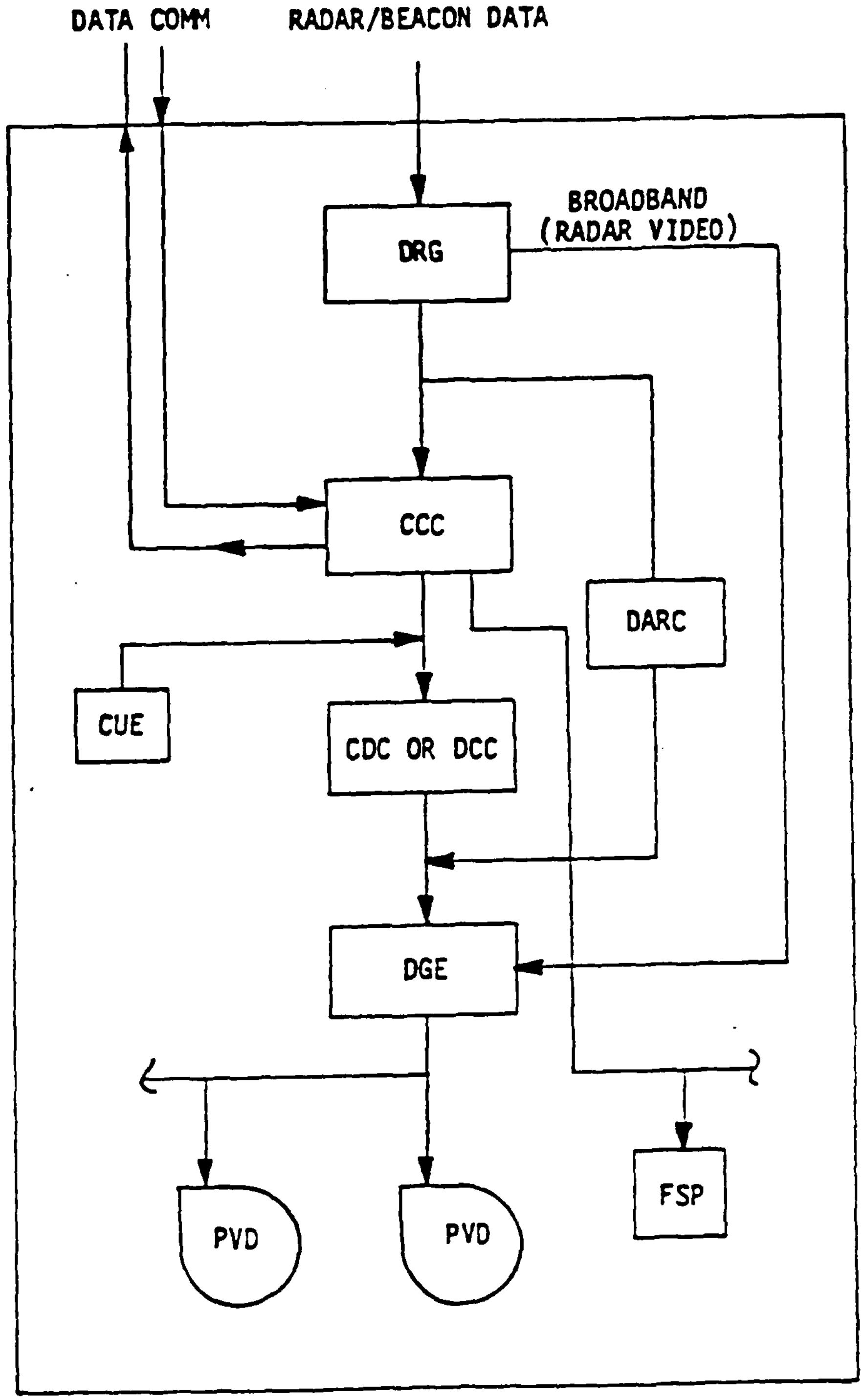
NOTE: SOME ARTS II AND RBDPE WILL HAVE DISPLAYS IN TOWER ONLY (TRACAB).



NOTES: 1) RADAR AND BEACON EQUIPMENT (ARSR, ASR, ATCBI) ARE SHOWN FOR CLARITY ONLY. THEY ARE NOT INCLUDED IN THIS STUDY.

2) OTHER SYSTEMS REQUIRED FOR OPERATIONS ARE NOT SHOWN.

FIGURE A-1



NOTES: 1) UP TO 60 OR MORE DISPLAYS (PVD) AND MANY FLIGHT STRIP PRINTERS (FSP) MAY BE PROVIDED.

2) THE RADAR VIDEO MAY BE DELETED AFTER DARC IS COMMISSIONED.

ARTCC AUTOMATION SYSTEM

FIGURE A-2

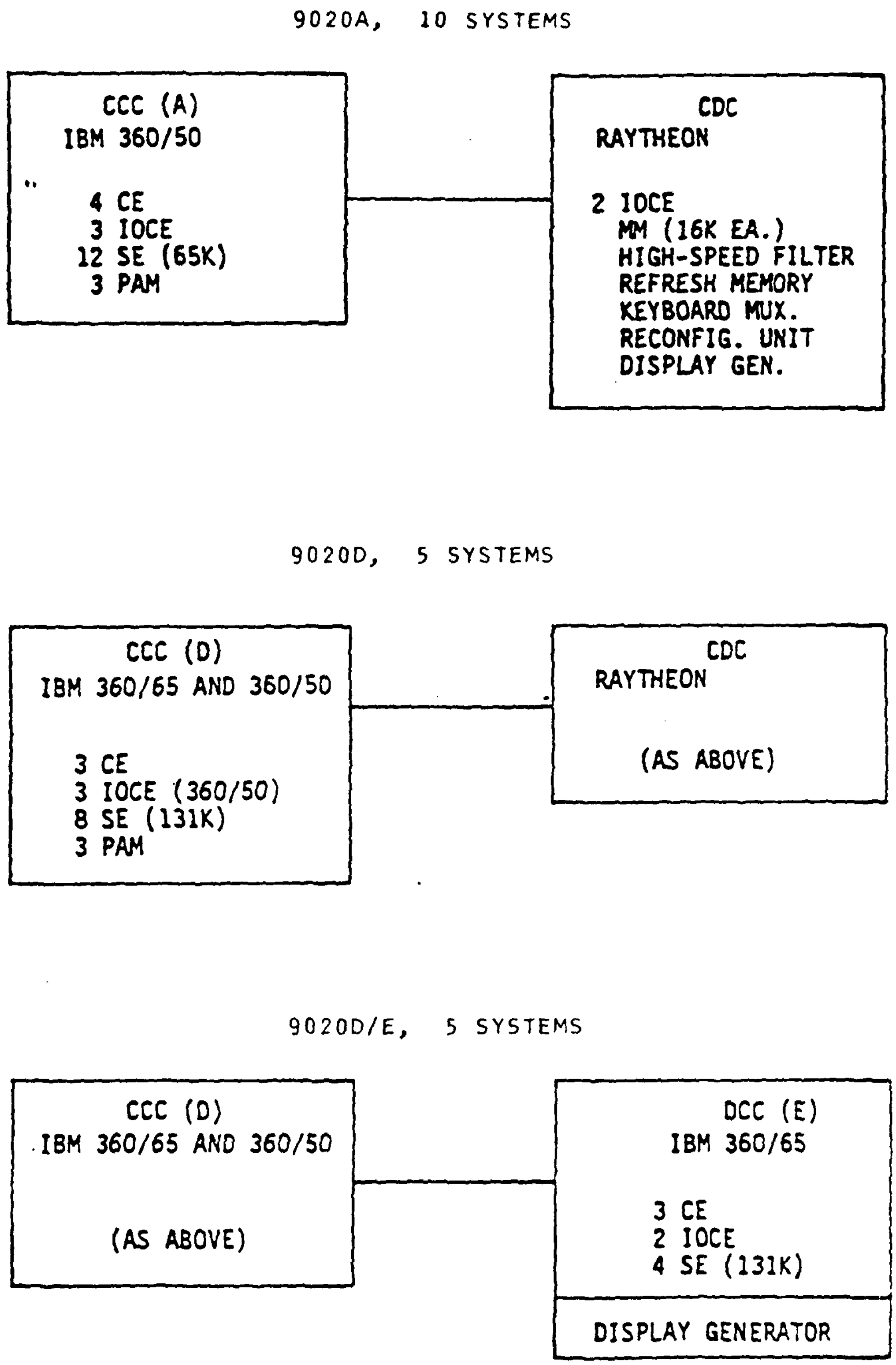
these systems and the numbers of each configuration in the 20 ARTCC's.

The 9020A CCC is a custom built IBM 360/50 configured as a multiprocessing subsystem with four Compute Elements (CE) and three Input/Output Control Elements (IOCE). Shared memory is provided by up to 12 Storage Elements (SE) of 65,000 word capacity each. The three Peripheral Adapter Modules (PAM) are custom designed multiplexers. A standard array of IBM System 360 peripheral devices complete this subsystem. Ten of these 9020A's are paired with ten Raytheon CDC's, at the smaller ARTCC's.

The 9020D CCC combines IBM 360/65 technology with the IBM 360/50. The CE's and SE's are the later design, but the IOCE's are the earlier design. Five of the 9020D's are paired with the Raytheon CDC, and five are paired with the IBM DCC which is of IBM 360/65 technology. In this configuration, the Display Generator (DGE) is a separate unit provided by Sanders Associates.

These systems normally operate continually (nearly 24 hours each day) in a real-time, fail-safe, fail-soft mode. One of each critical element (CE, SE, IOCE) of the system is treated as a spare module which can take the place of any counterpart on-line module if it fails. Realtime detection of failure and automatic reconfiguration are accomplished through a complex, highly sophisticated software system developed especially for the air traffic control environment. Reconfiguration may also be manually commanded.

Data entry devices are provided at the operating positions (PVD) to permit the Air Traffic Controllers to communicate with the system. Up to 60 online PVD's may be provided with the CDC, and 90 with the DCC.

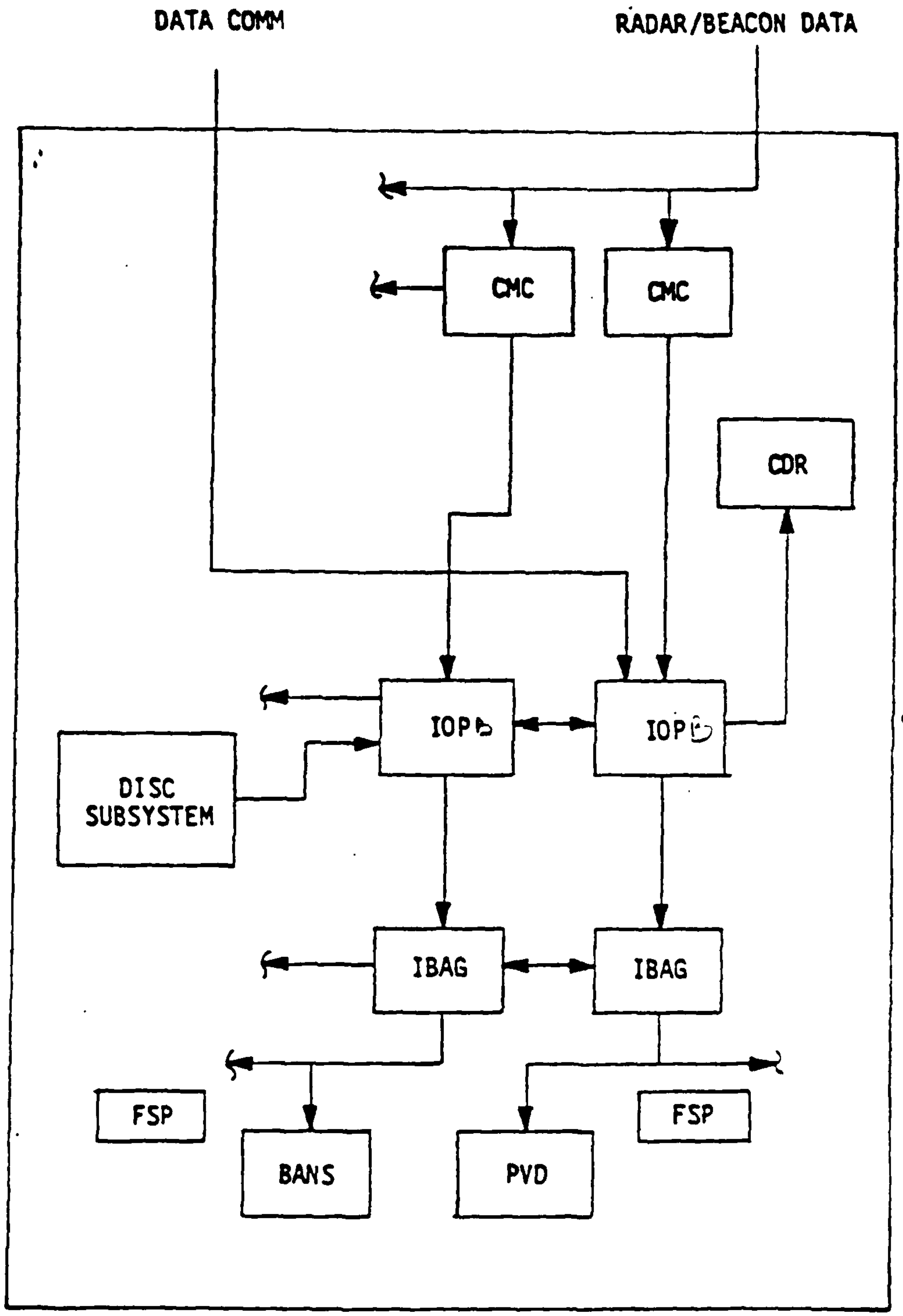


ENROUTE COMPUTER/DISPLAY SYSTEMS

FIGURE A-3

A-2.2 ENROUTE AUTOMATED RADAR TRACKING SYSTEM (EARTS). The EARTS system provides capability for both terminal and enroute control of air traffic at selected sites. It receives radar and beacon data from both short range Airport Surveillance Radars (ASR), and long range Air Route Surveillance Radars (ARSR) via Communication Multiplex Controllers, as indicated in Figure A-4. Local flight data (departure information) is received from local Flight Service Station (FSS). Flight data for all flights is received/sent on the Data Communications System (DCS). The processors (IOPB) are high speed, microelectronic, digital processors, supported by the disc subsystem. The Continuous Data Recorder (CDR) provides a record of critical data. Displays are connected through Interface Buffer Adapter Generators (IBAG). Tower displays using Brite Alphanumeric Systems (BANS), and terminal and enroute displays using Plan View Displays (PVD) are provided. Up to 48 displays can be provided with a maximum of 15 sensor (radar/beacon) inputs. EARTS provides an automated system for air traffic control for enroute airspace, terminal air space, and tower operations at Anchorage, Honolulu, San Juan, and Nellis AFB.

A-3.0 TERMINAL AREA SYSTEMS. Terminal airspace is at a lower altitude than enroute airspace, and surrounds landing and takeoff locations (airports). The short range radar/beacon with a range of 55-60 miles is used. In some locations, depending upon the terminal area, more than one radar/beacon and dual processors are necessary. The New York terminal area is the largest, extending from northern New Jersey to far out in Long Island, and utilizes four radar/beacon inputs. The air traffic control function in terminal areas is divided between "approach control" and airport tower direction of landings and takeoffs. The terminal radar



ENROUTE ARTS (EARTS)

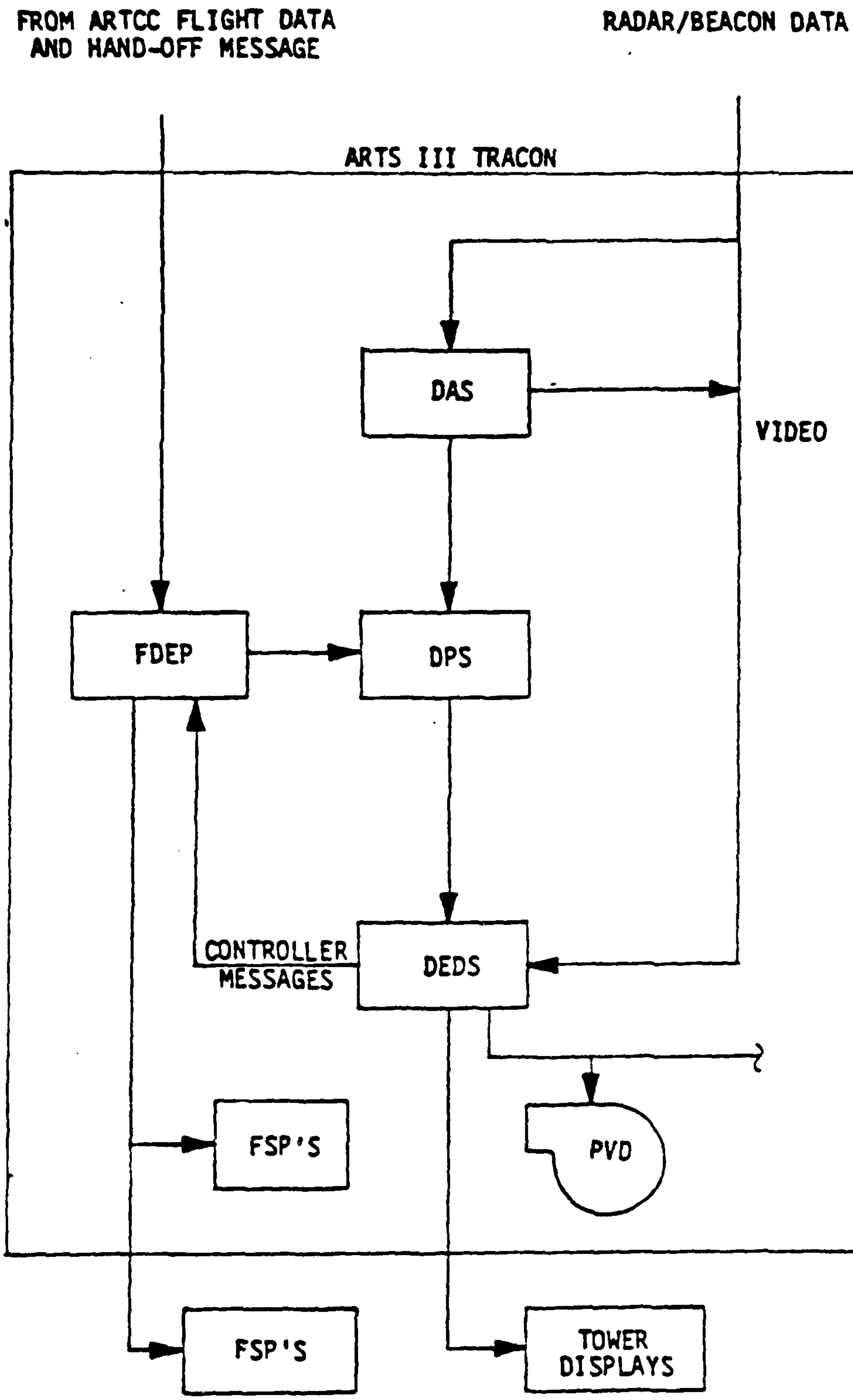
FIGURE A-4

approach controller "sees" the aircraft only on his electronic display. The tower controller has an electronic display but also can visually observe aircraft during final approach, landing, and takeoff. When visibility is reduced, then the tower controller must rely more on the electronic display.

Terminal systems include Automated Radar Terminal Systems (ARTS III/IIIA and ARTS II) and Radar Beacon Data Processing Equipments (RBDPE). ARTS IIIA will replace ARTS III at 62 major air terminal area and has replaced an ARTS IA at the NYCIFR. ARTS II will be installed at 71 Category II (smaller) airports between January 1979 and January 1981. Automated equipment is currently planned for 38 RBDPE's in operation at small airports.

A-3.1 ARTS III/IIIA SYSTEMS. ARTS III systems are currently operational at 63 major terminal areas. Many are located in a separate building at or near a major airport or on a lower floor of an airport tower. These are referred to as Terminal Radar Control (TRACON) facilities, except at military air bases. At Air Force locations they are Radar Approach Control (RAPCON) facilities. At Navy locations they are Radar Air Traffic Control Facilities (RATCF). Up to 10 displays can be provided in a terminal control room with accommodations for up to three controllers at each display. In addition, one or more displays are provided in the control tower(s) at major airports in the terminal area. The terminal area is divided into sectors, and each display shows only the sectors directed from that display.

Figure A-5 shows the major subsystems and data flow. Broadband Beacon video data is received in the Data Acquisition Subsystem (DAS), where it



AUTOMATED RADAR TERMINAL SYSTEM ARTS III

FIGURE A-5

is digitized and sent to the Digital Processing Subsystem in the form of digital messages. Radar video bypasses the computer system and goes directly to the Data Entry and Display Subsystem (DEDS).

Flight data and handoff messages are sent from the enroute center (ARTCC) via the DCN to the FDEP and to the Data Processing Subsystem (DPS). FDEP provides the flight data to flight printers in the control room, towers, and other facilities in the terminal area.

The DPS is a solid-state, digital, stored program computer. It detects beacon transponder equipped aircraft within the terminal area. It provides signals to control the dynamic display of alphanumeric data in the Data Entry and Display Subsystem (DEDS). Its operation is supported by magnetic tape. If two radar/beacon sites are used, or greater computing or storage capacity is required, two IOP's are used.

The DEDS provides the means for the controller to communicate with the sytem, principally by means of the keyboards located at each display. Both vertical and horizontal displays can be provided. A sophisticated set of controls allows the controller to select display parameters and thereby optimize the data and display to his needs. If the automated digital system fails, the video radar and beacon data is available to display the most essential data - the position of each aircraft.

A few ARTS III sites have an additional off-line equipment for adaptation and assembly of program (software) changes and additions - a Univac 9300, VI-C assembly subsystem. Each of these Central Support Facilities serve several other sites which do not have this capability. However, each ARTS IIIA will have this additional capability.

The airport tower control functions are usually divided into landing control, ground control, and takeoff control. The handoff from the terminal radar controller handling the approach sector to the landing controller usually occurs when each aircraft reaches the middle marker, about ten miles from touchdown. The tower display shows the position of all the aircraft on final approach, the data block of each transponder equipped airplane giving ID and altitude, the location of the middle marker, and the touchdown point. Spacing, alignment, and altitude are the most critical factors.

The display provides a better perception of this combination than either the pilot or the controller has by visual means. Beginning at the middle marker, the landing controller advises each pilot, as necessary, of corrections needed in heading, speed, altitude, spacing, etc. The ARTS systems are not suitable for controlling aircraft on the ground. The ground controller uses visual and, in a few locations, a separate ground radar system and display for direction of ground traffic. The takeoff controller's automated display shows the runway and departure route. His handoff to a terminal controller at the TRACON occurs very soon after takeoff, usually at a specified altitude and course, or when the departing aircraft reaches a certain marker or beacon. At each handoff, the pilot changes radio frequency to contact the next controller.

The terminal controller should know exactly where each departing aircraft will appear on his display, based on a printed flight strip for each one giving identity, route, destination, etc. When the pilot calls, he is prepared to assume control, direct each flight through his control area, and hand off to the next controller.

ARTS III is not a redundant system. A failure of any hardware or software element will degrade performance or cause the system to fail. The backup mode is the radar/beacon video. Further, the number of flight plans and tracks it has capacity for is limited to 175-220, depending on the equipment and software at each site.

ARTS IIIA will replace ARTS III at major terminal areas. ARTS IIIA is a redundant, fail-soft, modular programmable system with increased capacity. It includes a Continuous Data Recording System (CDR). A dual system has 600 track capacity. A single system has 300 track capacity. If a failure occurs, the system is designed automatically to diagnose and reconfigure both hardwre and software to continue operating, possibly at a reduced capacity. Radar tracking is an added feature. This increases the accuracy of tracking data and allows alphanumeric data blocks to be used for aircraft targets without an operable beacon transponder.

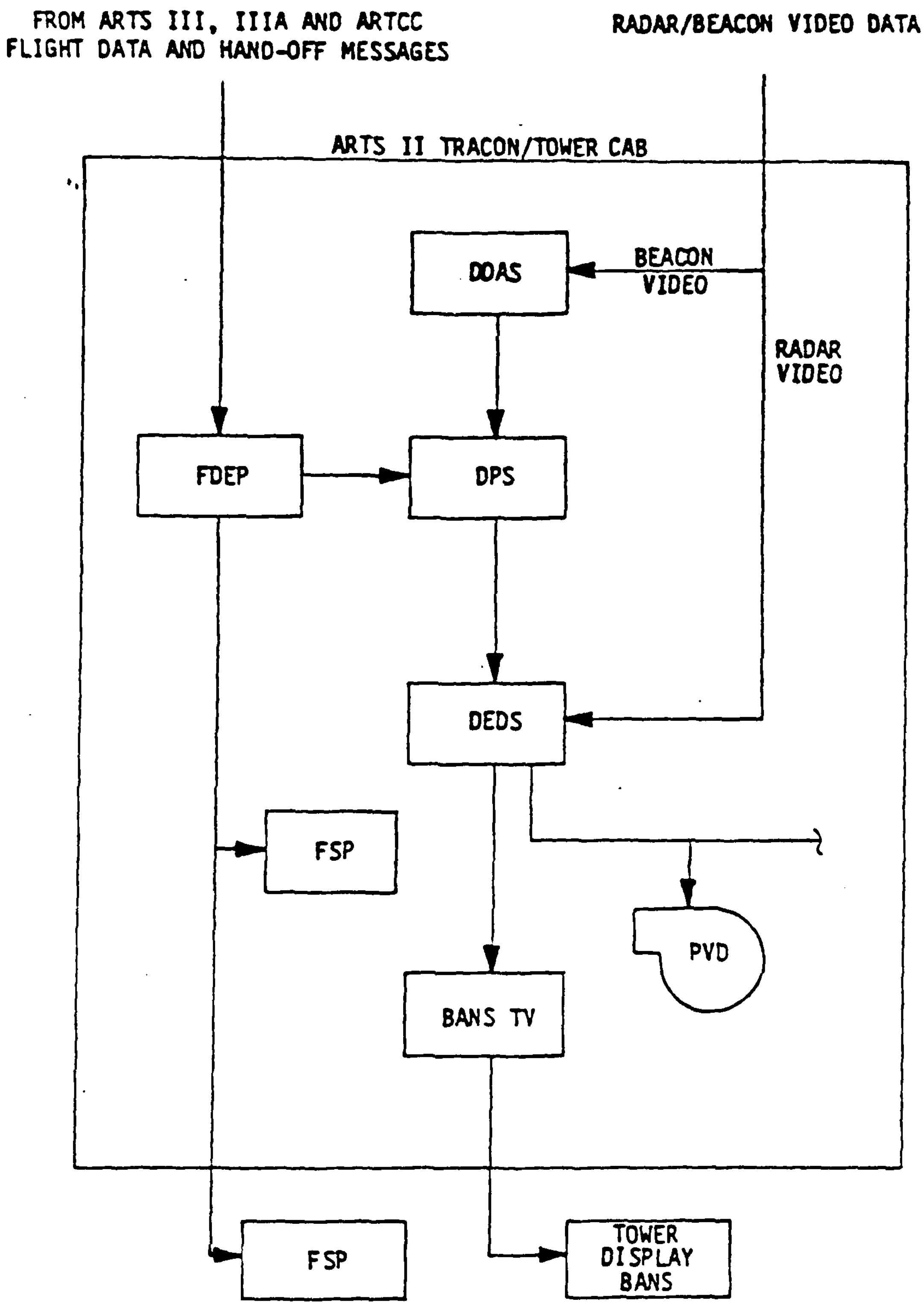
A-3.2 ARTS II SYSTEM. Medium and low density airports do not require the capacity and capability of an ARTS III/IIIA system. A smaller less expensive system, designated ARTS II, was developed for this application. ARTS II is an automated beacon, nontracking, alphanumeric system. The basic system provides four terminal displays, a maintenance display, and one tower display, but can be expanded to provide a maximum of ten operational displays. The ARTS III and enroute systems "track" aircraft but the ARTS II system does not. The "tracking" systems utilize course and speed information on each aircraft to anticipate its position at each next sweep of the antenna; and displays the aircraft at its next position, even if the beacon or radar does not receive a return signal on the next (or each) sweep. (Return signals can be blanked or not appear on each sweep for several reasons: weather conditions, aircraft turns, or

banks, etc.) The ARTS II does not anticipate aircraft position. It displays the signal returns it receives on each sweep, and displays "NB" in the alert field of the data block if a previous target airplane does not appear, to alert the controller, and displays only the last position received. ARTS II will also be supplied in a Tower Cab (TRACAB) configuration with a maintenance display and three tower displays. The ARTS II does not calculate or display ground speed. It provides a full alphanumeric data block for aircraft with a discrete code beacon, and numeric data only for non-discrete codes. ARTS II is similar to ARTS III in that:

- It is not a redundant system.
- If the digital system fails, but the radar video system does not fail, then it can display raw video radar target images as the backup operational mode.

The system has adequate capacity for the anticipated traffic load at medium and low density airports. Since it is not a "tracking system", its capacity is not limited by flight tracks, but by aircraft target displays. The basic ARTS II system can display up to 128 aircraft on each antenna sweep. The fully expanded ARTS II system can display up to 256 aircraft on each antenna sweep. However, the number of alphanumeric data blocks it can retain and display is severely reduced as the number of aircraft increases towards the capacity limits.

Figure A-6 shows the signal flow and major subassemblies of the basic ARTS II. The beacon video enters the Decoding Data Acquisition Subsystem (DDAS) where it is decoded and digitized before it is sent to the DPS. The radar video bypasses the digital computer system, and goes directly



ARTS II AUTOMATED TERMINAL SYSTEM

FIGURE A-6

to the display system. The DPS also receives flight data and handoff messages from the terminal center and the enroute center. The DPS stores flight data, matches it to beacon data received from DDAS, and sends it to the RADS. Four or more vertical displays and a maintenance display may be located in the TRACON and one or more in the airport tower cab, up to a total of ten displays each with one or two controller positions. The tower displays are obtained by televising the terminal display and projecting it on a BANS display. In the TRACAB configuration, a maintenance display and three BANS tower displays are provided.

A-3.3 RADAR BEACON DATA PROCESSING EQUIPMENT (RBDPE). During the time that FAA was implementing the ARTS III program for major air terminals, they were also involved in a joint military program directed at improved radar control for lower activity level airports, such as most military bases. The AN/TPX-42 equipment resulted from this effort. A joint procurement followed. FAA selected 38 lower activity level airports for installation of this equipment. Air Force and Navy procured 281 systems.

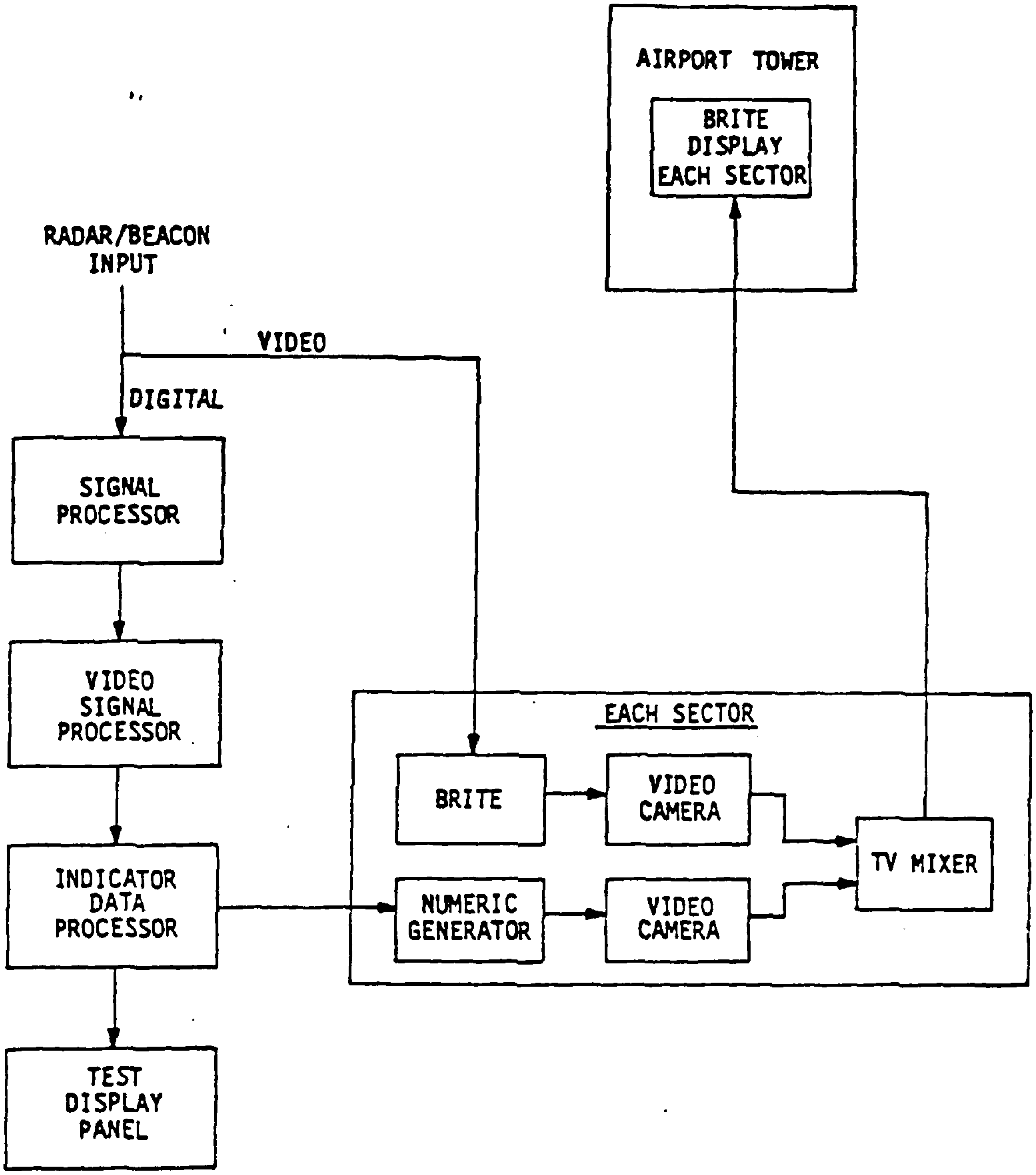
FAA terminology for the sytem is RBDPE. The system provides a Brite tower display for each sector using radar/beacon and sector video mapper inputs.

The display shows beacon/targets and radar video targets. The alphanumeric data block for beacon transponder equipped aircraft displays identity and altitude (for Mode C equipped aircraft). The maximum capacity of the system is 128 aircraft. The system is nonprogrammable and nonredundant.

Figure A-7 shows the signal flow and major elements of the system. Beacon video signals and the radar azimuth signal are processed by the signal processor and video signal processor. The indicator data processor output is in the form of digital words which identify the X-Y position, identity and altitude of each aircraft. The numeric generator interprets this digital output and displays the target locations and data block on a small PPI scope. A video camera provides a TV image of this data. The radar video target data is received and displayed on a similar small PPI scope. A second video camera provides a TV image of this data. A TV mixer superimposes the two pictures and sends the composite to the Brite display in the tower. The numeric generator provides the data for each sector, and the same set of sector processing equipment is required for each sector and tower display.

A modification to the basic AN/TPX-42 has been developed by USAF which is called the Programmable Indicator Data Processor (PIDP). It has capability similar to ARTS II, and is expected to upgrade existing equipment at 75 military sites. This new equipment will require data communications with FAA enroute centers.

A-3.4 <u>FLIGHT DATA ENTRY AND PRINTOUT (FDEP)</u>. The FDEP system is a two-way data communication system. Flight data is sent from the originating site of each flight to FAA facilities along the planned route and at the destination. Enroute center computers store the data required for control operations and forward flight data to ARTS sites, and airport facilities. At the automated flight control facilities, the flight data is typed out on a flight strip printer a few minutes prior to the scheduled arrival of each flight at the boundary of the controlled air space. Therefore, each controller has advance notice of all pertinent



NOTE: There are usually three or more sectors at each airport.

RBDPE (AN/TPX-42)

FIGURE A-7

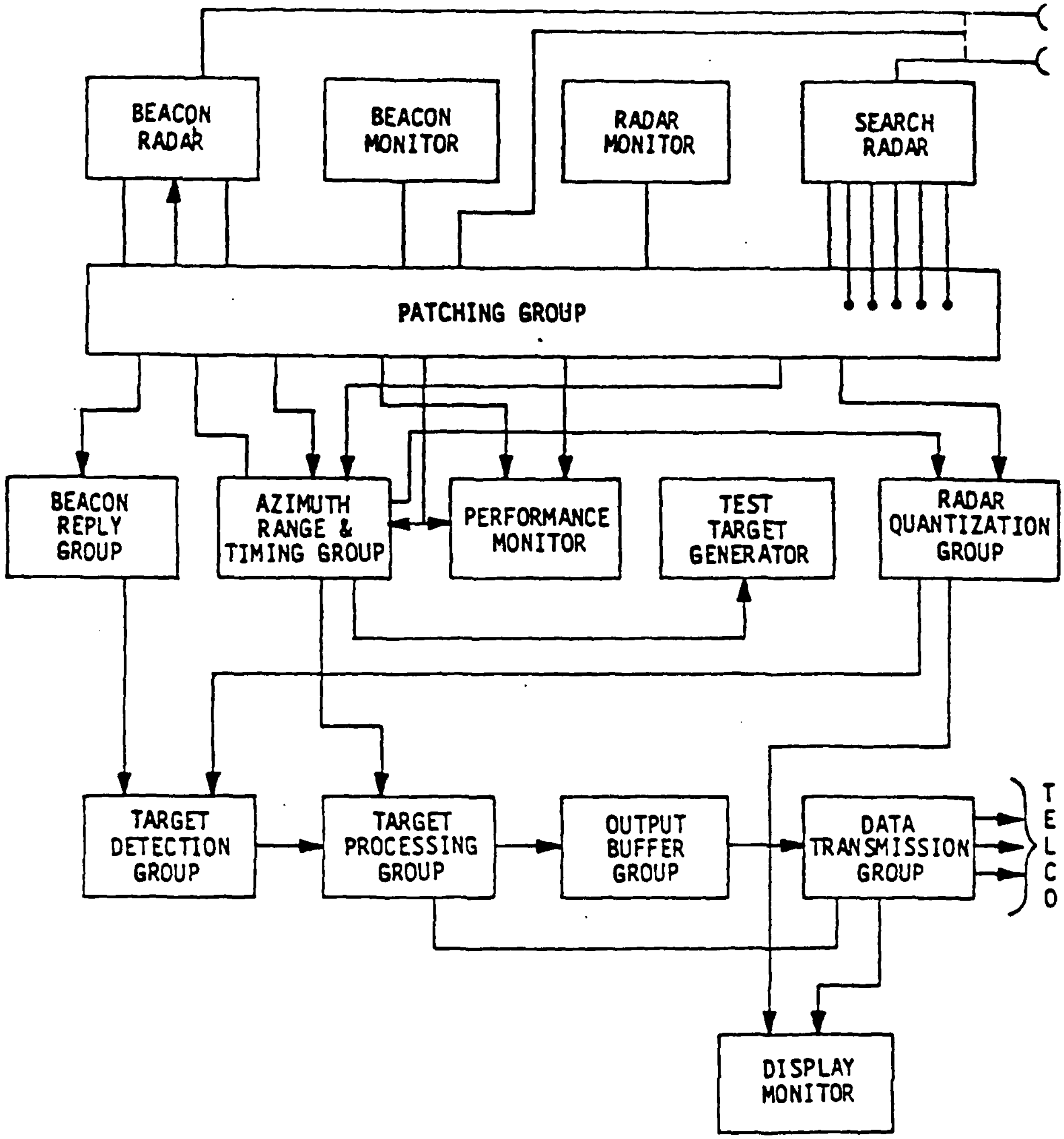
data on each flight before it enters his controlled area.

A-4.0 COMMON DIGITIZER (CD). The CD was developed and put in service at ARSR (mostly remote) sites, to convert analog radar signals to digital form, so they could be used in digital computers for automated processing display. The CD is located at the radar site so that telephone lines could be used to transmit the digital data, as well as the Radio Microwave Link (RML) system which is suitable for both analog video and digital signal data. In this way, a redundant path was provided for digitizer radar and beacon data, as well as a single path for radar video. The CD is a single-thread, or nonredundant equipment. If it fails, then digitized radar signals are not available from that site, but radar video signals would be available.

A block diagram of the CD is shown in Figure A-8. The CD receives inputs from both the primary search radar and the beacon radar. It detects radar targets which are then reinforced with validated beacon replies. Target messages are sent to the Data Receiver Group at the ARTCC via Telco and/or RML.

The Azimuth, Range and Timing Group provde the basic azimuth and range data. An azimuth pulse generator in the antenna pedestal normally provides azimuth clock and reference pulses.

The Radar Quantizer Group quantizes radar search video amplitude and range. The Beacon Reply Group detects and processes valid beacon reply code trains. Reply codes are transmitted between pairs of framing pulses. A line-up delay corrects the alignment of radar video signal with beacon video signal so that targets at the same range are processed



COMMON DIGITIZER

FIGURE A-8

correctly.

The Target Detection Group detects radar targets by examining the return signal history for each range cell over an azimuth time period. It counts the number of hits in the range cell and compares the hit count with criteria for leading and trailing target edges.

The Target Processing Group splits the return beam to determine target center azimuth, measures return signal azimuth angle length to see if the signal is a valid target, validates the beacon code, converts mode C altitude data to binary code and maintains the status record of targets.

The Output Buffer Group stores completed messages from the Target Processing Group, selects, formats, and transfers messages to the Data Transmission Group one bit at a time. The Data Transmission Group has three high speed channels for sending the digital output via Telco to the ARTCC and two low speed channels.

System performance is monitored by the Performance Monitor Group. If a malfunction occurs, it provides both visual and audible alarms. The Display Monitor provides both an electronic display and a printer to display output messages.

The present CD at 98 radar sites will be replaced by the new CD-2 between June 1981 and May 1983. CD-2 is a redundant, solid-state equipment which is expected to improve availability and reliability significantly. The CD-2 will be available in four configurations:

- Radar and Beacon (ARSR)
- Beacon Only (ATCBT)
- Joint Military/FAA
- Terminal Radar and Beacon (ASR)

The number on order is 115, with 15 additional as optional. Seven will go to the Academy, Depot, and NAFEC, leaving potential expansion from 98 to 123 sites, including 11 beacon only sites.

Appendix B

REVISED COST DATA

In response to the AF comment on items A.1.b.1 and A.1.b.2 for DARC, CD, and EARTS, the following information was obtained from AAF-360 at NAFEC. These data were not received in time to be incorporated in the tables and are, therefore, included as an appendix. The sub-totals and totals will also be impacted by these changes.

FY-80 ($000)

AF LABOR	DARC	CD	EARTS
NAFEC Hardware Support	663	198	-
NAFEC Software Support	60	-	226

FY 81 ($000)

AF LABOR	DARC	CD	EARTS
NAFEC Hardware Support	804	236	-
NAFEC Software Support	60	-	310

The entries for Fiscal Year 1981 are held constant for Fiscal Years 1982-84.

DATE
FILMED

8